Final Report to the Laguna Madre Interagency Coordination Team

March 1999

Temporal and Spatial Effects of Open Water Dredged Material Disposal on Habitat Utilization by Fishery and Forage Organisms in Laguna Madre, Texas

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INTRODUCTION

The Gulf Intracoastal Waterway (GIWW) was dredged through Laguna Madre, Texas, during 1945-1949 by the U.S. Army Corps of Engineers (Rickner 1979, Brown and Kraus 1996). Dredged materials were deposited in placement areas alongside the GIWW, and these placement areas continue to be used today for maintenance dredging on a 2-5 year cycle (Chaney et al. 1978). These dredged material deposits may have acute and chronic effects on seagrass habitats that cover much of Laguna Madre, their utilization by fishery and forage organisms, and overall system productivity. The periodic deposition of dredged material at designated sites may reduce the ecological value of the bottom through both direct effects (e.g., covering seagrasses or mudflats, smothering benthos, increasing turbidity, or exchanging one habitat [seagrass] for another [subtidal mudflat or emergent island]) and indirect effects (e.g., altering prey densities and compositions, or altering predation rates by reducing water clarity).

Observations on the potential disruptions caused by open bay placement of dredged material are not new. Disposal of dredged materials causes immediate, widespread, but usually short-term effects on water clarity (Windom 1975, Nichols et al. 1990). Turbidity increases, burial of seagrasses, spread of dredged material up to 400 m (0.25 mi) after 18 months, and only sparse regrowth of seagrass after 3 years were documented at a site in Redfish Bay, Texas, just north of Laguna Madre by Hellier and Kornicker (1962) and Odum (1963). After examining seagrasses and benthic communities at placement areas in Upper Laguna Madre, Rickner (1979) concluded that 10-20 years were needed to re-establish seagrass and benthic communities and recommended upland confined containment over open bay deposition. A study of dredging effects on water column light attenuation in Lower Laguna Madre indicated that elevated turbidity was detectable at the disposal site 15 months after deposition, at sites > 1.2 km away, and in adjacent seagrass beds up to 10 months after deposition (Onuf 1994).

Neither temporal extent nor spatial extent of these disturbances to floral and faunal communities have been documented in sufficient detail to make informed decisions on whether alternative methods of dredged material disposal in Laguna Madre are needed. Placement areas can be re-colonized by seagrasses, although re-colonization is not assured. An advance by shoalgrass *Halodule wrightii* of 3-4 m onto a dredged deposit in Upper Laguna Madre in less than 2 months was recorded by Circé (1979), although the deposit had apparently remained non-vegetated for 12 years. An unexpected seed-set of eelgrass *Zostera marina* on a previously non-vegetated dredge disposal site (age unstated) in Core Sound, North Carolina led to shoot densities and coverage similar to the edge of adjacent natural beds within 6 months (Fonseca et al. 1990). However, Sheridan (1998) found no colonization of dredged material at two sites in Lower Laguna Madre after 3 years, probably because the placement sites were subject to relatively strong currents and sediment instability. Odum's (1963) observations that seagrasses were just beginning to colonize the edges of a deposit after 3 years and Rickner's (1979) data indicating reduced seagrass shoot densities even after 10 years are the only indications of the time frame needed for seagrass re-colonization of dredged material deposits in Laguna Madre.

Faunal recovery after dredged material deposition has not been well studied, particularly with reference to seagrass habitats. Placement areas in Coos Bay, Oregon experiencing chronic disturbance from passing ship wakes exhibited rapid re-colonization by benthos within 7 days, presumably because the community was adapted to disturbance (McCauley et al. 1977). An open water disposal site in Long Island Sound supported densities of annelids similar to those in control areas within 7 months, although mollusc densities had not reached parity after 12 months (Rhoads et al. 1977). A shallow (1 m) subtidal sand deposit in Apalachee Bay, Florida attracted high densities of annelids and crustaceans within 3 months, but the benthic assemblage did not resemble that of nearby seagrass beds after 12 months (Subrahmanyam 1984). In Upper Laguna Madre, Rickner (1979) reported that mollusc and polychaete species compositions and densities in seagrass beds that had colonized dredge deposits that were > 10 years old were similar to those in adjacent natural seagrass beds. A reconnaissance survey of benthic communities in placement areas and adjoining seagrass beds in both Upper and Lower Laguna Madre found few differences in species assemblages (Espey, Huston & Associates, Inc. 1998). Six of the placement areas had been used within 5 years and six had not been used for 7-13 years. Thus, it seems that benthic communities may take up to 10 years to reach parity.

As for nekton (fishes and decapods), there are indications that mobile organisms can respond quickly to dredged material deposits but that community alterations persist through time.

Repeated observations 1.5-3 years after deposition indicated that fish densities of non-vegetated dredged material and seagrass habitats in Lower Laguna Madre did not differ significantly, but community compositions were distinctive (Sheridan 1998). In that study, decapod densities were always significantly lower at dredged material sites but species compositions were similar to those in seagrasses. However, once dredged material deposits were colonized by seagrasses, there were no differences in nekton communities between colonized placement areas and natural seagrass beds. Unfortunately, the ages of the seagrass-colonized deposits were unknown. Elsewhere, Fonseca et al. (1990) offered a single observation that a 6 month old, naturally re-seeded eelgrass bed on a disposal site contained similar densities of fishes and shrimps as the edge of nearby natural beds in Core Sound, North Carolina . Brown-Peterson et al. (1993) compared seagrass and fish communities of natural seagrass beds and colonized beds 31 years after dredging of the Atlantic Intracoastal Waterway in Indian River Lagoon, Florida. Persistent differences in seagrass shoot densities and fish species composition were noted, even though fish densities were similar in most seasons. Thus, re-establishment of seagrass in an area does not assure the re-establishment of fishery habitat value.

The objectives of this project were to determine how long alterations in habitat and in habitat use were detectable and, secondarily, to determine how far away from a placement site such effects might be felt. Dredged materials may exhibit both acute and chronic effects on flora and fauna stemming from the immediate burial of habitats, migration of sediments away from placement sites, elevations in turbidity during and after placement, release of ammonium and sulfide, and wind-driven resuspension events prior to sediment stabilization (Onuf 1994, Brown and Kraus 1996, Cifuentes et al. 1997); whether these impacts persist over a typical dredging cycle (2-5 years) is unknown. These data were collected to assist the U.S. Army Corps of Engineers (ACE) in determining whether dredging operations should be modified to maintain productivity and to improve habitat value of placement areas for fishery species and other estuarine fauna.

This project analyzed maintenance dredged material that was placed during early 1995 at three sites each in Upper Laguna Madre and Lower Laguna Madre. At each site, three habitats were examined: mud deposits that typically bury seagrasses; seagrasses within 5 m of the deposits that received little fresh mud but were expected to experience high turbidity and other indirect effects of material placement; and undisturbed seagrasses about 1 km away. Seasonal water column parameters, surface sediment characteristics, seagrass biomass and coverage, benthic communities, and densities of fishery species and forage organisms were measured and compared during fall and spring over a 3-year period (1995-1998). Certain sections of the Laguna Madre system, particularly Upper Laguna Madre, have experienced a bloom of the brown tide alga *Aureoumbra lagunensis* since 1990. It was intended that presence or absence of brown tide would be factored into the study, even though it was unknown what effects the brown tide might have on re-colonization of dredged material (Onuf 1996, Street et al. 1997).

MATERIALS AND METHODS

Area Description

Laguna Madre is a barrier island estuary extending 200 km from Corpus Christi Bay south to the Rio Grande delta on the U.S.-Mexico border. The lagoon is separated into Upper Laguna Madre and Lower Laguna Madre by a large depositional fan known as the Land Cut which forms wind-driven tidal flats in the middle of the estuary (Morton et al. 1998). The Gulf Intracoastal Waterway, completed in the late 1940's, forms the only permanent connection between the two lagoons.

Site Selection

Maintenance dredged material was deposited in 13 placement areas (PA) in Lower Laguna Madre and in 9 PAs in Upper Laguna Madre during late 1994 and early 1995 (N. McLellan, ACE, Galveston, Texas, pers. comm.). Historically, maintenance dredging operations in Laguna Madre have spread material over an entire placement area located along side the GIWW. In recent operations including the present one, dredged material has been directed into a small number of discharge corridors within each placement area in order to localize impacts to submerged and emergent habitats. All sites were visited in August 1995 to determine whether placement areas were partially to totally subtidal, whether new materials could be located, and whether placement areas supported seagrasses nearby and at a distance of 1 km. Only the following six sites had those required components (Maps 1 and 2): Upper Laguna Madre, PA 187: 27° 27.08' N, 97° 20.00' W; PA 194: 27° 20.85' N, 97° 22.95' W; and PA 197; 27° 17.18' N, 97° 24.32' W; Lower Laguna Madre, PA 211: 26° 47.53' N, 97° 28.01' W; PA 221: 26° 30.71' N, 97° 28.31' W; and PA 222: 26° 29.00' N, 97° 23.02' W. Positions were located by GPS (Garmin International, Model 38, Olathe, Kansas; accuracy 100 m). Morton et al. (1998) examined pre-construction bathymetric maps and post-construction aerial photographs of four of these sites. They concluded that three sites (PAs 197, 211, and 221) likely supported seagrasses prior to construction of the

GIWW, while one site (PA 187) was probably too deep. Based on present bathymetry of the remaining sites, I believe that PA 194 was probably too deep while PA 222 was as shallow or shallower than PA 221 and thus supported seagrasses prior to 1945.

Dredged material was placed on PAs 187, 194, and 197 in January 1995 and on PAs 211, 221, and 222 in March 1995. Projected placement volumes by site were: 187 = 77,420 m^3, 194 = 127,830 m^3, 197 = 160,650 m^3, 211 = 130,050 m^3, 221 = 95,625 m^3, and 222 = 123,930 m^3. Each of these placement areas had fringing seagrasses that partially or completely surrounded the site. The closest natural seagrass beds that were not near adjoining placement areas and were of similar depth ranges were all located west of the selected placement areas. This was not expected to influence results of floral and faunal surveys, since Rickner (1979) indicated that floral and benthic density indices were not related to whether collections were made east or west of placement sites.

Sampling/Experimental Design

Sampling was designed to test whether habitat utilization patterns of flora and fauna were directly affected by dredged material placement and to estimate how long it takes for a new placement site to resemble nearby undisturbed seagrass sites. Sample sets were collected 6 times over 3 years, beginning in September 1995 (about 6 months after dredging) and continuing in April and September 1996, May and September 1997, and April 1998. Sampling was scheduled for fall and spring seasons because fish and decapod abundances in general, and those of fishery species in particular, were expected to be relatively high (Hellier 1962, Hoese and Jones 1963, Stokes 1974, Monaco et al. 1989) and any dredging impacts might be more easily detected. Benthic community densities, which were expected to be intermediate to low (Montagna and Kalke 1992), were examined concurrently as an index of food availability for fishes and decapods.

The six chosen sites spanned 20 km of Upper Laguna Madre and 30 km of Lower Laguna Madre. As originally proposed, three sites were to be located in areas relatively unlikely to be affected by brown tide, and three Sites were to be located in areas usually experiencing brown tide, apportioning sites among Upper Laguna Madre and Lower Laguna Madre to avoid potential confounding of sources of variation. However, brown tide was consistently visible only at Placement Areas 187, 194, and 197 in Upper Laguna (August 1995 preliminary site visit and September 1995, April and September 1996, and May 1997 sampling trips). Brown tide abated in Upper Laguna Madre during the summer of 1997 and was not seen in the final two sampling periods (September 1997, April 1998). Brown tide was seen in Lower Laguna Madre at Placement Areas 211, 221, and 222 only in May 1997, although it may have been there at low densities. Therefore, the original scheme of brown tide affected versus unaffected sites was confounded by the biogeographic split between Upper Laguna Madre and Lower Laguna Madre.

Power analyses (Sokal and Rohlf 1981) of unpublished NMFS data concerning variability of fish, decapod, and benthos densities in Texas seagrass habitats indicated that 30 replicate samples per habitat would allow detection of a 100% difference in means at $\alpha = 0.10$ and $1-\beta$ (= power) = 0.80. At each of the 6 sites, we designated three habitats: Maximum Impact (subtidal muds near the center of the placement area, devoid of seagrasses at the start of the study); Minimum Impact (within 5 m of the edge of dredged material, where turbidity was likely to remain high but seagrasses were still growing); and Natural Seagrass (beds approximately 1000 m or more away from the site). Five randomly placed replicate sample sets (described below) were taken within each habitat at each site, yielding the required 30 replicates per habitat. Lengths (north-south) and widths (east-west) of Maximum Impact habitats were measured by range finder (Ranging Inc., Model 1200, Rochester, NY; accuracy ± 1.8 m at 91 m) during each site visit to give a qualitative estimate of non-vegetated mud surface area remaining.

In addition, samples were also collected at one site (PA 194) in seagrasses between the Minimum Impact zone and Natural Seagrass to determine the range of potential habitat alterations. PA 194 was chosen because it held the second largest initial deposit and the material was placed on the windward side of an island, potentially leading to long-term turbidity increases over downwind seagrass deposits. Sampling was scaled to reflect conditions at orders of magnitude distances (1-5 m, 10-15 m, 100-105 m, and 1000^{+} m) beyond the fresh dredge deposit. Thus, five extra sample sets were collected at 10-15 m and 100-105 m distances per site visit in addition to the regular sample sets.

Sample sets included the following types of quantitative data collected from within the perimeter of, or immediately adjacent to, the macrofaunal sampler (a drop trap, described below). Temperature, salinity, depth, and turbidity were measured within the drop trap before any other activities (except there were no turbidity samples from Lower Laguna Madre during April 1996). Temperature was measured with a YSI Model 55 meter (YSI Inc., Yellow Springs, Ohio). Salinity was measured with a temperature-compensated refractometer. Minimum and maximum depths were measured with a meter stick. Water samples for turbidity analysis were collected in screw cap bottles and later tested in the laboratory with an HF Scientific Model DRT100B turbidimeter (HF Scientific, Ft. Myers, Florida). Surface sediments (0-5 and 5-10 cm) were collected by 5-cm diameter corer to examine organic content and grain size following methods of Dean (1974) and Folk (1980). Since organic materials were not removed prior to grain size analyses, the terms "rubble", "sand", "silt", and "clay" actually refer to rubble-sized, sand-sized, silt-sized, and clay-sized particles. Exclusive grain size limits were: rubble > 2 mm, sand > 0.0625 mm, silt > 0.0039 mm, and clay <0.0040 mm (Folk 1980). Rubble was tabulated but not analyzed further since it consisted mainly of shell and seagrass fragments. Seagrass shoot and root/rhizome biomasses (g dry weight; all species combined) were measured from benthic cores (described below), and seagrass coverage was determined with a 1 m^2 quadrat with 25 grid cells following methods of Dunton (1990) and Fonseca et al. (1987). Coverage was derived from the presence or absence of at least one live shoot in a grid cell. Benthic infauna and epifauna inhabiting the top 5 cm of sediments (including seagrass shoots) were collected with a 5-cm diameter corer (3 pooled cores per site) and sieved through 0.500-mm mesh following methods of Sheridan and Livingston (1983). Benthic organisms were monitored as an index of potential foods for fishes and decapods. Densities of nekton (fishes and decapods) were estimated with a 1 m^2 drop trap deployed from the bow of a boat during daylight hours (Zimmerman et al. 1984). Recent research in Florida Bay seagrasses using the same type of gear indicated no nekton community differences between day and night collections (Sheridan et al. 1997). All water was pumped out of the drop trap through a 1-mm mesh plankton net into a removable mesh bag. Any organisms remaining on the bottom were removed and added to the mesh bag. For the purposes of this study, fishery species were defined as those species of recreational and commercial value monitored by Texas Parks and

Wildlife Department and National Marine Fisheries Service (Campbell et al. 1991, National Marine Fisheries Service 1995, Robinson et al. 1997). Fishery species that were captured in this study included brown shrimp *Farfantepenaeus aztecus*, pink shrimp *F. duorarum*, white shrimp *Litopenaeus setiferus*, blue crab *Callinectes sapidus*, spotted seatrout *Cynoscion nebulosus*, spot *Leiostomus xanthurus*, Atlantic croaker *Micropogonias undulatus*, sheepshead *Archosargus probatocephalus*, southern flounder *Paralichthys lethostigma*, and gulf menhaden *Brevoortia patronus*.

Data Analysis

Data collected in this study during each sampling period were analyzed using 2-way analysis of variance (ANOVA) to assess effects of locale and habitat over all sites or 1-way ANOVA to assess effects of distance at PA 194. Locale was defined as Upper Laguna Madre or Lower Laguna Madre and, as previously noted, coincidentally indicated the usual presence or absence of brown tide. Data were transformed prior to ANOVA as follows: arcsine for proportions such as seagrass coverage, sediment organic content, and sand/silt/clay; log (x+1) for seagrass biomass, benthos, and nekton. Multiple comparison of treatment means employed Ryan's Q test (first 5 sampling periods) or Scheffé's test (last sampling period), the change being due to a switch in computer software from SAS (SAS Institute Inc. 1985) to Statistica (StatSoft Inc. 1997). Both Ryan's Q and Scheffé's tests are powerful, conservative, and recommended for general use (Day and Quinn 1989). Tables and figures present non-transformed means.

RESULTS

Sediments: Qualitative surveys of the placement areas indicated fresh mud deposits ranging in estimated size from 1,400 m^2 (PA 221) to 187,000 m^2 (PA 197) in September 1995. Areas of soft, non-vegetated mud remaining generally trended downward over time for all sites except PA 197 (Figure 1). Declines were relatively rapid at PAs 211 and 221. The deposit at PA 211 was placed on the leeward side of islands created during the original dredging of the GIWW, so the mode of "disappearance" of non-vegetated mud was most likely compaction and re-vegetation by seagrasses rather than wind-induced dispersal. The deposit at PA 221 was unprotected by any island and thus was exposed to a long fetch of southeasterly winds which predominate along the Texas coast (Brown and Kraus 1996). Sediments at this site were probably dispersed by winds and wave action. Declines in non-vegetated mud at Placement Areas 187, 194, and 222 were relatively slow (Figure 1). Deposits at PAs 187 and 194 were placed around the northern, eastern, and southern edges of previously created dredged material islands, thus they were relatively unprotected from southeasterly winds. Rapid re-vegetation was noted at these two sites between the final two observations, presumably indicating some degree of sediment stability (winnowing of fines by currents tended to produce a crust of sand and shell overlying the deposits) and compaction. Placement at PA 222 resulted in deposits on the southern and northern ends of two previously created dredged material islands separated by a narrow, shallow channel. The southern deposit appeared to be spreading over time as it washed off the end of the island while the northern deposit re-vegetated rapidly, with the net effect of slow overall decrease in non-vegetated area. Again, the rapid re-vegetation noted at PA 222 between the final two observations presumably indicated some degree of sediment stability. Changes in non-vegetated mud area at PA 197 indicated the least re-vegetation over time (Figure 1). This was the largest deposit and it was placed on the windward side of an old dredged material island experiencing a long southeast fetch. The variation in estimated area indicated that materials may have been spreading out over time. Although an estimated 45% of the dredged material was "lost", the slow re-vegetation was most likely due to wind-induced sediment disturbance. The pooled effect of all 6 sites was a sharp drop (60% of initial) in non-vegetated mud area between September 1995 and

April 1996, a relatively stable period of 18 months (probably due to spreading at PA 197), and a final sharp drop (50% of remaining mud) in non-vegetated area between September 1997 and April 1998 (Figure 1). The end result was an apparent 75% reduction in non-vegetated mud surface area after 3⁺ years.

There were few trends in surface sediment characteristics consistently attributable to either locale or habitat (Table 1). Locale was the overwhelming factor controlling silt content which was always significantly higher in Lower Laguna Madre than in Upper Laguna Madre (monthly means, 0-5 cm depth, 8.17-12.77% vs 3.77-5.17%, respectively; Appendix 1). Clay content was always higher in Upper Laguna Madre than in Lower Laguna Madre but not always significantly so (monthly means, 0-5 cm depth, 22.16-37.28% vs 17.19-36.50%, respectively; Appendix 1). In the early months after deposition, there were occasional significant differences in organic content and in sand or clay proportions attributable to habitat. Organic material tended to be somewhat lower in the Minimum Impact habitat immediately adjacent to the dredged material deposits, and clay contents were generally higher in the Maximum Impact habitat (Appendix 2). Sand content was quite variable among habitats. Over time, differences in surface sediment organic content and fines (silt + clay) attributable to habitat declined (Figures 2-3), indicating loss of fine materials from Maximum Impact habitats or sediment stabilization or both within 1.5 years of deposition.

Comparison of surface (0-5 cm) and subsurface (5-10 cm) sediments was thought to be a simple means of determining whether wind-induced resuspension and re-distribution was moving dredged material away from the sites after placement. It was hypothesized that elevated surface organics or silt and clay contents could indicate such movement of materials. With few exceptions sand, silt, and clay proportions were significantly correlated between surface and subsurface deposits in all three habitats (Appendix 3), so this metric was not proven to be useful. Most of the exceptions were found in clay contents of Natural Seagrass habitats, which tended to have more clay in subsurface deposits (Appendix 2). There was also a lack of correlation in organic content between sediment depth ranges for both Minimum Impact and Natural Seagrass habitats (Appendix 3). This was expected in Minimum Impact habitats due to proximity to mud deposits: as this habitat "moved" toward the center of the original dredge deposits, surface and subsurface sediments became more similar (seagrass was growing over the deposits which were relatively homogeneous). The lack of consistent correlation between surface and subsurface organic contents in the Natural Seagrass habitat is more likely due to local variations in biological activity than to deposition following wind-induced turbidity plumes.

Water Column: Among the water column characteristics, significant differences in temperature, salinity, and depth were almost always linked to locale, with values in Upper Laguna Madre exceeding those in Lower Laguna Madre (Table 2). These differences were not always large and may not have been biologically meaningful. For example, mean water temperature usually differed by $\leq 2°$ C and mean depths differed by $\leq$ 10 cm over all sites (Appendix 4). However, mean salinity differed by up to 15 ‰ (Figure 4), so there might be reason to suspect differences in floral and faunal species composition and density between Upper Laguna Madre and Lower Laguna Madre based on salinity. Water temperature was significantly related to habitat on occasion, but this was rarely seen for salinity (Table 2). Again, these differences were small (Appendix 5) and probably did not affect the flora and fauna. Depth was consistently greatest in Natural Seagrass (Table 2), as was expected. Significant differences in turbidity due to either habitat or locale were rarely seen, but there was a seasonal component. Turbidity was higher in spring than in fall, most likely due to higher wind speeds. Although turbidity was significantly higher in Maximum Impact habitats during the first two sampling periods (Figure 5), there were no habitat-related differences detected in later months (Table 2, Appendices 4-5). Thus, on-site turbidity increases following dredged material placement seemed to disappear after approximately 1.5 yr.

Seagrass communities: Differences in seagrass community characteristics were occasionally significantly related to locale (Table 3, Appendix 6), but there were no consistent trends over time and thus no apparent linkage to either higher salinity or presence of brown tide characteristic of Upper Laguna Madre. A possible exception was the root : shoot ratio (RSR) which was significantly lower in Upper Laguna Madre than in Lower Laguna Madre during 4 of 6 sampling periods. This could indicate brown tide effects in Upper Laguna Madre that either increased shoot biomass (e.g., producing taller shoots or broader leaves in a reduced light environment) or decreased rhizome biomass (e.g., no change in shoot morphology but draining stored energy reserves). Alternatively, this trend might be linked to the higher salinity typical of Upper Laguna Madre that was noted previously.

However, there were always significant differences in seagrasses attributable to habitat. Coverage, shoot and root biomass, and root : shoot ratio (RSR) in the Maximum Impact habitat were always significantly less than in either Natural Seagrass or Minimum Impact habitats or both (Table 3). The lone exception was RSR in April 1998 which was not significantly different among habitats. Dredging was completed during January or March 1995, and during the first three sampling periods (1.5 years post-deposition) seagrass coverage in the Minimum Impact habitats within 1-5 m of bare mud areas was significantly less than that of Natural Seagrass, even though the differences were minor (both exceeded 90% coverage at all times; Table 3, Appendix 7). Both habitats continued to support significantly higher coverages than the Maximum Impact habitat throughout the study period. It must be remembered here that seagrasses were colonizing from the edges of the original deposits inward; thus, as coverage in the Maximum Impact habitat increased slowly over time (Figure 6), the actual non-vegetated area contracted. The presence of colonizing seagrasses in the Minimum Impact habitat also explains why shoot biomass and root biomass in that habitat were usually intermediate between mature communities in Natural Seagrass and first colonists in Maximum Impact habitats (Figure 7). Initial samples taken during September 1995 were likely in established beds at the edge of new mud deposits with biomass similar to Natural Seagrass habitats, but later biomass samples came from newly colonized deposits that were sparse relative to Natural Seagrass habitats. Thus, it took until September 1997 (2.5 years) for seagrasses on the edge of dredged material deposits to develop above- and below-ground biomass similar those found away from the deposits (Table 3). The RSRs indicated few differences in seagrass health between Natural Seagrass and Minimal Impact habitats, but seagrasses collected from Maximum Impact habitats tended to have low RSRs (Figure 8), indicating stress or lack of below-ground materials storage or both.

Seagrasses began colonizing the Maximum Impact habitats between September 1995, when paddle grass *Halophila engelmannii* found at PA 197 was the only seagrass noted at any site, and April 1996, when shoalgrass *Halodule wrightii* was found at all 6 sites (Table 4).

Shoalgrass was the predominant seagrass in the study areas and was found in all habitats except the Maximum Impact habitat at PA 197, where paddle grass was the only colonist during the study period. Paddle grass was also found frequently in Minimum Impact habitats in both Upper Laguna Madre and Lower Laguna Madre. Wigeongrass *Ruppia maritima* was only recorded during the second half of the study when it was most common in the Minimum Impact habitats. Manatee grass *Syringodium filiforme* was found primarily in Lower Laguna Madre at Placement areas 221 and 222 and once in Upper Laguna Madre near PA 197. This last record may indicate the continued northward movement of manatee grass which spread from south to north in Lower Laguna Madre between 1965 and 1988 (Quammen and Onuf 1993). However, scattered patches of manatee grass had been reported previously in the northern part of Upper Laguna Madre (Simmons 1957). Turtlegrass *Thalassia testudinum* was recorded only near PAs 221 and 222 (Table 4).

Benthic Communities: Benthic sampling revealed a diverse community of over 220 taxa comprising 78145 individuals (Appendix 8). Most benthic organisms were annelids (59% of the total), followed by non-decapod crustaceans (34%), molluscs (6%), and miscellaneous taxa (1%). Both the Natural Seagrass and Minimal Impact habitats yielded about 2.5 times as many organisms as the Maximum Impact habitat. The Maximum Impact habitat yielded the fewest benthic organisms each month (Figure 9). Most organisms were relatively rare: of all the organisms collected, only 20 taxa each composed more than 1% of the total (>780 individuals over all collections; Table 5). The remainder of this results section will address the three major phylogenetic groups and the most abundant species.

Natural Seagrass habitat yielded 3 times as many annelids and Minimum Impact habitat yielded 2 times as many annelids as Maximum Impact habitat (Appendix 8). Densities of total annelids were always significantly higher in Natural Seagrass habitat than in Maximum Impact habitat and were almost always so in Minimum Impact habitat (Table 5). Some of these differences in density were relatively large, for example by a factor of 5-6 in May and September 1997 (Figure 9). Total annelid densities were not consistently related to locale, although when significant differences were noted these densities were higher in Lower Laguna Madre.

Minimum Impact habitat yielded 3 times as many crustaceans and Natural Seagrass habitat yielded 2 times as many crustaceans as Maximum Impact habitats (Appendix 8). Densities of total crustaceans were always significantly higher in Minimum Impact habitat than in Maximum Impact habitat and were almost always so in Natural Seagrass habitat (Table 5). These differences in density were relatively large in both September 1995 and April 1998, when high densities of the amphipod *Cerapus benthophilus* were collected (Figure 9). Total crustacean densities were not consistently related to locale.

Molluscs were the only group closely related to locale, with densities significantly higher in Upper Laguna Madre than in Lower Laguna Madre on 4 of 6 occasions (Table 5). This was not always the case with the dominant mollusc species. The bivalve *Anomalocardia aubergiana* was abundant during four sampling periods and densities were significantly higher in Upper Laguna Madre on two occasions, but the other abundant bivalve *Mulinia lateralis* was only numerous during two sampling periods and no trends could be discerned. Neither densities of molluscs in general nor densities of the two dominant species were consistently related to habitat. In fact, total mollusc densities by habitat were similar (Appendix 8) and there were no trends in monthly total mollusc or *Anomalocardia* densities among habitats (Figure 9, Table 6).

There were 14 taxa of annelids among the 20 most abundant taxa found over all collections (Table 5). Densities of *Capitella capitata*, *Exogone dispar*, and *Polydora ligni* were not related to either locale or habitat. Monthly densities of *Capitella* and *Exogone* by habitat are given in Table 6, and *Capitella* is shown in Figure 10 to indicate its relatively constant densities. *Exogone* was abundant only during September 1995, April 1996, and September 1997, and *Polydora ligni* was extremely abundant during September 1996 (up to 300 per core at some sites). Densities of *Hydroides dianthus*, *Naineris bicornis*, *Polydora socialis*, and *Sabaco elongatus* were significantly related to both locale and habitat but were only abundant on one occasion each so it was not possible to develop any trends for them. Densities of *Streblospio benedicti*, *Melinna maculata*, and *Heteromastus filiformis* were all significantly related to locale, in that they were more abundant in Lower Laguna Madre than in Upper Laguna Madre, but they were not related to habitat. Monthly habitat-related densities are given for *Streblospio* in Table 6 only because it was so numerous. *Prionospio heterobranchia*, unidentified Oligochaetes, *Syllis* *cornutus*, and *Chone cf. americana*, were generally consistently related to habitat and less so to locale. Densities of the latter four taxa were usually greater in Natural Seagrass or Minimum Impact habitats or both than in Maximum Impact habitat (Table 6, Figures 10-11).

There were 4 taxa of crustaceans among the 20 most abundant taxa (Table 5). Densities of the amphipod *Grandidierella bonnieroides* were not consistently related to either locale or habitat, although they were typically lowest in Maximum Impact habitat (Table 6, Figure 11). Densities of the isopod *Erichsonella attenuata* and the amphipods *Cerapus benthophilus* and *Ampelisca* spp. were significantly related to both locale and habitat. *Erichsonella* was abundant only twice but was primarily found in Upper Laguna Madre in Natural Seagrass and Minimum Impact habitats. *Cerapus* was most abundant in Upper Laguna Madre and usually in Minimum Impact habitat, where large numbers were found in tubes attached to seagrass leaves particularly during September 1995 and April 1998 (Table 6, Figure 11). *Ampelisca* spp. (primarily juveniles and probably a mixture of *A. abdita* and *A. vadorum*) were most abundant in Lower Laguna Madre and in Minimum Impact habitat (Table 6, Figure 11). This species is also a tube dweller, and the tubes can be found attached either to seagrass leaves or to the bottom.

Given the patterns in densities of major benthic groups and individual taxa (Figures 9-11), there is not much indication that benthic communities in Maximum Impact habitat had begun to recover. The upturns in total benthos, annelid, and crustacean densities observed in April 1998 were similar to those observed in April 1996 and likely represented the remnants of the usual late winter - early spring peak in benthic faunal densities observed along the Texas coast. The May 1997 collections did not demonstrate this peak and may have been collected too late in the annual cycle. Mollusc densities were the exception, since there seemed to be no consistent relation between density and dredging impact in periodic collections and since total numbers collected were in highest in impacted habitats. Among the numerically abundant benthic organisms, there were no taxa that exhibited high densities in all three habitats at any time even 3^+ years after deposition (with the exception of *Ampelisca* spp. in April 1996).

Nekton communities: Sampling for fishes and decapods revealed a diverse community of 79 taxa comprising 20636 individuals (Appendix 9). Decapods outnumbered fishes by a three to one margin. Both the Natural Seagrass and Minimal Impact habitats yielded about 2.5 times as many fishes and about 9 times as many decapods as the Maximum Impact habitat. With one exception, the Maximum Impact habitat yielded the fewest fishes and decapods each month (Figures 12-13). The 15 most abundant species comprised 93.1% of all nekton collected (Appendix 9). The remainder of this section will address the major phylogenetic groups and the most abundant species.

Natural Seagrass habitat yielded 2.2 times as many fishes and Minimum Impact habitat yielded 2.6 times as many fishes as Maximum Impact habitat (Appendix 9). Densities of total fishes were significantly higher in Natural Seagrass and in Minimum Impact habitats than in Maximum Impact habitat on 5 of 6 sampling dates (Table 7). Habitat-related differences in fish densities tended to be greater during the early sampling periods and narrower later in the study, and fish densities in the Maximum Impact habitat may have begun increasing by April 1998 as seagrasses colonized more of the mud deposits (Figure 12). Total fish densities were not consistently related to locale, although when significant differences were noted these densities were usually higher in Lower Laguna Madre.

Minimum Impact habitat yielded 9.6 times as many decapods and Natural Seagrass habitat yielded 8.5 times as many decapods as Maximum Impact habitats (Appendix 9). Densities of total decapods were always significantly higher in both Natural Seagrass and Minimum Impact habitats than in Maximum Impact habitat (Table 7). These differences in density tended to be larger in September than in April or May (Figure 13). In addition, there was a definite spike in decapod densities in April 1998 that was likely connected with the increased seagrass coverage of mud deposits. Total crustacean densities were not consistently related to locale.

There were five taxa of fishes among the 15 most abundant macrofaunal taxa found over all collections (Table 7). Gulf menhaden *Brevoortia patronus* and bay anchovy *Anchoa mitchilli* were only abundant on one or two occasions each (Table 8), so it was not possible to develop any locale- or habitat-related trends for them. Most of the gulf menhaden were captured in May 1997, when densities of up to 278 individuals m^{-2} were found in the Maximum Impact habitat at PA 221. Most bay anchovies were collected in September 1995 at PA 194 when densities reached up to 107 individuals m^{-2}. These species are both schooling, open water planktivores that are not known to orient toward submerged vegetation. Pinfish *Lagodon rhomboides* and gulf pipefish *Syngnathus scovelli* were consistently related to habitat and rarely to locale (Table 7). When abundant, densities of these two taxa were usually greater in Natural Seagrass or Minimum Impact habitats or both than in Maximum Impact habitat (Table 8, Figure 12). Code goby *Gobiosoma robustum* was consistently related to both locale and habitat (Table 7). This species was more abundant in Lower Laguna Madre and in Natural Seagrass and Minimum Impact habitats. Pinfish, gulf pipefish, and code goby are epibenthic organisms that are known to prefer vegetated habitats over non-vegetated habitats.

There were 10 taxa of decapods among the 15 most abundant macrofaunal taxa (Table 7). Ridgeback mud crab *Panopeus turgidus* and hermit crab *Pagurus criniticornis* were only relatively abundant on one occasion each, thus no locale- or habitat-related trends in density could be defined. Half of all ridgeback mud crabs and 75% of all *P. criniticornis* were collected from one sample in the Minimum Impact habitat at PA 222 in September 1996, and most of the remaining individuals of both species were collected nearby during that month. Densities of brackish grass shrimp *Palaemonetes intermedius*, brown shrimp *Farfantepenaeus aztecus*, and blue crab *Callinectes sapidus* were significantly related to both locale and habitat (Table 7). Brackish grass shrimp was more abundant in Upper Laguna Madre, while brown shrimp and blue crab were more abundant in Lower Laguna Madre. All three species were consistently more abundant in Natural Seagrass or Minimum Impact habitats or both than in Maximum Impact habitat (Table 8). Although no change in density of brackish grass shrimp in Maximum Impact habitat was noted over time, densities of both brown shrimp and blue crab seemed to increase during April 1998 coincident with improved seagrass coverage of that habitat. Densities of bigclaw snapping shrimp *Alpheus heterochaelis* appeared to be significantly related to habitat only, although this species was relatively abundant on just two occasions. In fact, only three of 352 individuals of this species were collected from Maximum Impact habitat (Appendix 9). Densities of gulf grassflat crab *Dyspanopeus texana*, zostera shrimp *Hippolyte zostericola*, daggerblade grass shrimp *Palaemonetes pugio*, and arrow shrimp *Tozeuma carolinense* were significantly related to habitat but not to locale (Table 7). When these four species were relatively abundant, their densities in Natural Seagrass or Minimum Impact habitats or both were significantly higher than in Maximum Impact habitat (Table 8). Zostera shrimp and daggerblade grass shrimp were perhaps the most habitat-specific, with only 11 of 935 individuals and 5 of 781 individuals, respectively, collected outside of seagrasses (Appendix 9).

Juveniles of a variety of economically important species were collected. Menhaden, blue crab, and brown shrimp have already been discussed. All other species were characterized by relatively low densities. Sheepshead *Archosargus probatocephalus*, spotted seatrout *Cynoscion nebulosus*, pink shrimp *Farfantepenaeus duorarum*, and white shrimp *Litopenaeus setiferus* individually and collectively were more numerous in Natural Seagrass or Minimum Impact habitats and were rarely captured in the Maximum Impact habitat (Appendix 9). However, spot *Leiostomus xanthurus* were collected from all habitats, and Atlantic croaker *Micropogonias undulatus* and southern flounder *Paralichthys lethostigma* were somewhat more numerous in Maximum Impact habitat.

The patterns in nekton densities (Figures 12-14) indicate that macrofaunal communities in Maximum Impact habitat perhaps had begun the recovery process as of the last collections in April 1998. The upturns in total fishes, total decapods, code goby, zostera shrimp, gulf grassflat crab, and blue crab observed in April 1998 coincided with increases in seagrass coverage and above-ground biomass. However, other taxa abundant in adjacent Natural Seagrass and Minimum Impact habitats had not returned to Maximum Impact habitat even 3^{+} years after deposition.

Spatial scale of effects: One site, PA 194 in Upper Laguna Madre, was selected to determine whether alterations in community parameters extended into intermediate distances from the Maximum Impact habitat. Each month, five additional sample sets each were collected at 10-15 m and 100-105 m distances from the Maximum Impact habitat, enabling assessment of effects at scales of 1 m (Minimum Impact), 10 m, 100 m, and 1000 m (Natural Seagrass) away from the Maximum Impact habitat. It must be remembered that the power of ANOVA tests for these comparisons was low due to the small number of samples ($n = 5$) collected in each habitat at any one time.

Surface and subsurface sediment characteristics are summarized in Table 9 and Appendix 10. There were no consistently significant differences in surface sediment characteristics among samples collected at 1, 10, 100, and 1000 m distances from the Maximum Impact habitat. However, there were some trends in the data. Surface organic content was usually highest at the placement site (4.54-8.62%) and up to 15 m away (2.41-8.09%). At 100-1000 m distances, surface organic content reached a maximum of 4.43% and was usually lower. Similar trends were observed for subsurface organic content. As expected, the combined surface silt + clay content was highest at the Maximum Impact habitat (32.57-76.51%), intermediate at 1-5 and 10-15 m distances (19.62-80.13%), and lowest at 100-105 and 1000^{+} m distances (13.56-33.28%). Trends in surface sand content were the reverse of those for fines. Subsurface silt + clay content was typically lower than surface silt + clay content in the Maximum Impact habitat, but this was not seen elsewhere; in fact, this trend was reversed in Natural Seagrass.

Water column characteristics are summarized in Table 9 and Appendix 11. There were no consistently significant differences in water column turbidity or depth among distance ranges outside the Maximum Impact area (Table 9); however, temperature tended to be higher at 100-105 m and 1000^{+} m ranges and salinity tended to be higher at 1-5 m and 10-15 m ranges. These differences were minor (Appendix 11) and were likely of no biological consequence. As expected, mean turbidity was highest at the Maximum Impact habitat (13.3-43.0 NTU), intermediate at 1-5 and 10-15 m distances (4.3-28.6 NTU), and lowest at 100-105 distances (5.5-15.0 NTU). Mean turbidity in Natural Seagrass occasionally reached high levels (e.g., 36.4 NTU in April 1998) probably because sampling sites were near the shoreline.

Seagrass community characteristics are summarized in Table 9 and Appendix 11. Seagrass coverage increased over time from 0% to 48.8% in the Maximum Impact habitat, but there were no consistent differences in seagrass coverage among distance ranges outside of the Maximum Impact habitat. Seagrass shoot biomass was usually significantly higher at 10-15 m, 100-105 m, and 1000^{+} m distances than at 1-5 m distances, and root biomass was usually significantly higher at 100-105 m and 1000^{+} m distances than at 1-5 m and 10-15 m distances. These trends were expected since seagrasses were growing from the edges of the deposit inward. Both seagrass shoot biomass and root biomass increased in the Maximum Impact area over time. There were no consistent differences in root : shoot ratio (RSR) outside the Maximum Impact habitat, which consistently had the lowest RSR.

Benthic community information is presented in Table 9 and Appendix 12. Over the six sampling periods, none of the three major taxa (annelids, non-decapod crustaceans, molluscs) nor any of the 23 dominant taxa exhibited consistently significant differences in densities among sampling zones outside the Maximum Impact area, with two exceptions. On at least three of the six sampling dates, the annelids *Prionospio heterobranchia* and *Trypanosyllis vittigera* were significantly more abundant at the 1000^{+} m distance than elsewhere. Data from all collections were pooled to look for qualitative trends in species distributions (Appendix 12). The total numbers of annelids, crustaceans, and miscellaneous taxa were higher outside the Maximum Impact area but were relatively similar in magnitude across the distance ranges away from each deposit. The total number of molluscs, however, decreased as distance from the dredge placement area increased. Sixteen taxa each composed at least 1% of the total number of individuals collected (n = 17709), and together these taxa comprised 80.7% of the total. The annelids *Capitella capitata*, *Chone cf. americana*, *Exogone dispar*, and *Melinna maculata* exhibited no trends in distribution of total numbers. Species with relatively large numbers collected within the Maximum Impact habitat included the annelids *Sabaco elongatus* and *Streblospio benedicti* and the bivalve *Anomalocardia aubergiana*. The remaining taxa generally exhibited higher total numbers outside of the Maximum Impact habitat, including the annelids *Naineris bicornis*, *Prionospio heterobranchia*, *Syllides fulvus*, *Trypanosyllis vittigera*, and unidentified Oligochaetes, the amphipod *Grandidierella bonnieroides*, and the isopod *Erichsonella attenuata*. The amphipod *Cerapus benthophilus* and the bivalve *Amygdalum papyria* exhibited high total numbers in the Minimum Impact areas within 15 m of the dredge deposit.

Macrofaunal community information is presented in Table 9 and Appendix 13. Over the six sampling periods, neither total fishes, total decapods, nor any of the 13 dominant taxa exhibited consistently significant differences in densities among sampling distances outside the Maximum Impact area. Data from all collections were pooled to look for qualitative trends in species distributions (Appendix 13). The total numbers of fishes, decapods, and all of the dominant species (with the exception of menhaden) were higher outside the Maximum Impact area but were relatively similar in magnitude across the distance ranges away from each deposit.

DISCUSSION

Temporal effects of dredged material disposal

The variety of system components studied here indicates that the effects of dredged material placement continue for at least 1.5 years for some facets and well beyond 3 years for others. The areal extent of non-vegetated mud decreased by 75% over the study period (3^+ years after deposition). Most of the remaining mud at five of the six sites examined was either in shallow or deep water and may re-vegetate slowly, if at all, due to tidal exposure and high water temperature at the shallow end or to reduced water clarity and light availability at depths > 1 m if disturbances such as the brown tide re-appear (brown tide was reported to have bloomed again in the summer of 1998; K. Dunton, University of Texas, pers. comm.). Total reduction in non-vegetated mud at these five sites was 86-99% after 3^+ years. However, there was still a large area of bare mud at one placement area (55% of estimated original area) at the end of the study period which might take at least 5 years to re-vegetate.

Surface sediment organic content, surface sand/silt/clay ratios, and water column turbidity seem to stabilize after 1.5 years and become similar to those attributes in surrounding Minimum Impact and Natural Seagrass beds. Prior to that time, sediments are subject to wind-induced resuspension both from strong but short-lived northerly winds and from persistent southeasterly winds (Onuf 1994, Brown and Kraus 1996). Seagrass colonization of the Maximum Impact habitat became noticeable after 2^+ years and was significant after 3^+ years. In other words, it became increasingly likely that dredged material had some seagrass growing on it in 2-3 years. This is the same time frame observed by Odum (1963), and the rapidity of coverage at some sites between observation periods was similar to the rapid growth onto dredged material over a two month period observed by Circé (1979). The lag between deposition and seagrass coverage may be due to a combination of physical disturbance by winds and currents and chemical inhibition by pore water constituents such as ammonium or sulfide, both of which can be toxic to seagrasses (Carlson et al. 1994, Van Katwijk et al. 1997). A previous study of dredged material placement sites in Lower Laguna Madre indicated extremely high levels of ammonium (> 900 μM) in recently placed sediments and elevated ammonium concentrations up to 3 years after placement (Sheridan 1998). High sulfide concentrations (235-1125 μM H_2S; Cifuentes et al. 1997) have been detected at placement areas that exceed those typical of Laguna Madre seagrass beds (< 200 μM H_2S; Pulich 1985). As these pore water constituents are released or oxidized, sediments presumably become more amenable for seagrass colonization. This would explain why seagrass shoot biomass, root biomass, and root:shoot ratio were increasing but remained low in the Maximum Impact habitat even after 3^+ years.

Once seagrasses begin to cover the bare mud and form Minimum Impact habitat, increases in densities of the mobile macrofauna can be expected (Fonseca et al. 1990). Nekton and benthos communities in Minimum Impact and Natural Seagrass habitats were similar in density and species composition over the study period. The total fish and total decapod communities, as well as several of the more abundant species such as code goby, zostera shrimp, brown shrimp, gulf grassflat crab, and blue crab, in the Maximum Impact habitat were showing signs of recovery after 3^+ years even though densities remained low. The sparse seagrasses there were likely beginning to provide structure and shelter. However, one of the other functions ascribed to seagrass beds that is linked to their support of high nekton densities is the provision of food, and benthic food resources had not shown signs of recovery in Maximum Impact habitat even after 3^+ years. Densities of annelids and non-decapod crustaceans remained much reduced and none of the dominant species increased in the Maximum Impact habitat, although densities of molluscs were higher there than elsewhere. Based on these observations, recovery of the benthos and nekton communities in Maximum Impact habitat would not be expected before 5-10 years. This is roughly the recovery period proposed by Rickner (1979) for benthos, who concluded that 10-20 years were needed for recovery. The discrepancy between the two recovery periods likely stems from Rickner having no study sites between the ages of 3 months and 10 years old. Based on seagrass growth patterns, however, the Maximum Impact habitat would have mostly disappeared within 5 years (Figure 15). Thus, the impact to fishery and forage organisms declines over time, seemingly in tandem with the disappearance of non-vegetated mud. The present dredging program for the Gulf Intracoastal Waterway is a 5 year cycle, in which high maintenance reaches may be dredged every 2 years and low maintenance reaches may not be dredged all. Placement areas that receive dredged material at least once during that period would barely have time to completely recover before being impacted again, while high use placement areas would never recover completely (presuming they did not become emergent). Continued use of open bay disposal in high maintenance reaches near Port Mansfield in Lower Laguna Madre causes chronic light reduction and has led to extensive losses of seagrasses from waters deeper than 1 m (Onuf 1994).

Spatial effects of dredged material disposal

Dredging and materials placement have acute and chronic effects on water transparency that could effect floral and faunal communities in different ways at different distances from the activity. Worst-case turbidity plumes caused by active dredging in waters > 2 m deep, while detectable up to 5 km away, usually dissipate within several days (Windom 1975, Nichols et al. 1990). Biotic effects of this acute stress are likely to be similar to those encountered by a series of cloudy days when sunlight is reduced or windy days when sediments are re-suspended and block sunlight either in the water column or as a film over submerged surfaces. The present project addressed chronic effects of dredged material deposition since it began after dredging was completed. In a previous study, increases in turbidity of shallow waters (< 2 m deep) following deep water (> 2 m) placement of dredged materials in Lower Laguna Madre were detectable over 1.2 km away for up to 10 months (Onuf 1994). Thus, there was a need to assess whether or not this effect was observed following shallow water deposition and whether location of the Natural Seagrass habitats at about 1 km from placement areas indeed represented undisturbed waters. Based on the study of one placement area, there were no consistently significant differences in most of the parameters measured at scales of 1, 10, 100, and 1000 m away from the Maximum Impact habitat. There were minor differences in temperature and salinity that were unlikely to cause differences in flora or fauna, but there were no consistent differences in turbidity. Large-scale, wind-induced water movements, such as might be found during a period of high winds over the entire Laguna Madre, were more likely to deliver turbid water throughout the study habitats than chronic, low level erosion from the deposits in a microtidal environment. Chronic turbidity effects were also expected to diminish as seagrasses vegetated the shallow deposits. There were some differences in seagrass shoot and root biomass that were likely connected to the colonization of dredged material. There were few consistently significant differences in either benthos or nekton populations among distance ranges. In part this stems from previous observations that as soon as an area becomes vegetated, the micro- and macrofauna colonize quickly (Fonseca et al. 1990).

This aspect of the study could have benefitted from a greater sampling effort. The small number of replicates collected per distance range ($n = 5$) provided very low power to any statistical tests. Because of this, the possibility for spatial effects between the immediate dredge material placement site and supposed undisturbed seagrasses has not been resolved effectively, even though there appear to be no consistent responses by sediments, water column, flora, or fauna. Undisturbed Natural Seagrass habitats could be found closer to placement sites, but positioning them at ≥ 1 km distances still seems conservative.

Brown tide impacts

The original intent of this study was to compare sites that were typically impacted by brown tide to sites that were usually free of brown tide. Twenty-two placement areas between Corpus Christi Bay and the Brownsville Ship Channel were utilized during the 1994-1995 dredging cycle, but only six of them were amenable to research concerning burial and re-growth of seagrasses. Three sites were in Upper Laguna Madre and three sites were in Lower Laguna Madre, which unfortunately coincided with the prevalence of brown tide in Upper Laguna Madre during this study. Thus, the potential impacts of brown tide were confounded by potential biogeographic differences between the two water bodies. The only other environmental factors that were consistently linked with either locale were silt content, which was 2-3 times greater in Lower Laguna Madre and was accompanied by a reduced clay content, and salinity, which was up to 15 ‰ higher in Upper Laguna Madre. The differences in silt and clay content were expected. Three sites were located in northern Lower Laguna Madre where sediments are primarily sand and silty sand (White et al. 1986), while the remaining sites in southern Upper Laguna Madre were located near Baffin Bay which contains a large proportion of clay in the sediments (White et al. 1989). The salinity differential was also expected, with salinity expected to be higher in Upper Laguna Madre due to lack of freshwater inputs (Quammen and Onuf 1993).

Brown tide has affected the distribution and biomass of seagrasses. Dunton (1994) recorded a 50% decline in below-ground biomass of shoalgrass during 1990-1993 which was reflected in reduced RSR values. Continued brown tide resulted in mortality of over 9.4 km^2 of seagrass in waters deeper than 1.4 m by 1995 (Onuf 1996). The fact that RSR values in the present study were significantly reduced in Upper Laguna Madre compared to Lower Laguna Madre in four of six sampling periods argues that there may have been brown tide effects on plant carbohydrate reserves. However, relatively rapid coverage of dredged materials by seagrasses was seen at two of three sites in Upper Laguna Madre, indicating that light reduction due to brown tide was not severe enough to prevent colonization of shallow (< 1 m) mud deposits under investigation.

Brown tide may also impact the Laguna Madre fauna, although direct toxic effects have not been found and food web disruptions are more likely (reviewed by Street et al. 1997). In the present study, there were no indications that any of the dominant organisms had been excluded from Upper Laguna Madre as dominants were found in both systems. Some of the dominant taxa in the present study were significantly more abundant in one locale over the other. The annelids *Streblospio benedicti*, *Melinna maculata*, and *Heteromastus filiformis* and the amphipod group *Ampelisca* spp. were all more abundant in Lower Laguna Madre than in Upper Laguna Madre. Data collected prior to brown tide in 1977-1978 by White et al. (1986, 1989) indicated the same pattern for *Streblospio* and *Ampelisca*, the reverse for *Melinna*, and no pattern for *Heteromastus* which was rare in their collections (patterns based on total individuals relative to total number of benthic grab samples). In the present study, total molluscs, the isopod *Erichsonella attenuata*, and the amphipod *Cerapus benthophilus* were significantly more abundant in Upper Laguna Madre than in Lower Laguna Madre. These distributions were all similar to those noted prior to the brown tide (White et al. 1986, 1989). Thus, brown tide does not appear to have affected benthic communities to any great extent, aside from a decline in the bivalve *Mulinia lateralis* (Street et al. 1997). Among nekton collected in the present study, code goby, brown shrimp, and blue crab were usually significantly more abundant in Lower Laguna Madre than in Upper Laguna Madre.

However, there have been no comparative studies of the densities of small nekton between the two locales prior to the brown tide bloom (Texas General Land Office 1995, Tunnell et al. 1996), so it is impossible to tell whether brown tide has affected their distribution and abundance patterns.

McEachron and Fuls (1996) tabulated annual mean catch rates of fishery organisms for 1976-1994 using bag seines, trawls, and gill nets to assess various life stages. Comparison of catch rates during 1985-1989 (before brown tide) and 1990-1994 (during brown tide) for 12 fishes and 4 decapods indicated the following: 1) sheepshead, southern flounder, gulf menhaden, and striped mullet *Mugil cephalus* exhibited no changes, based on data from all three types of gear; 2) red drum *Sciaenops ocellatus*, spotted seatrout, sand seatrout *Cynoscion arenarius*, Atlantic croaker, gafftopsail catfish *Bagre marinus*, spot, blue crab, and brown shrimp exhibited no changes, based on data from two of three gear types; and 3) there were indications that black drum *Pogonias cromis* catch rates were up sharply and that pinfish *Lagodon rhomboides*, white shrimp, and pink shrimp catch rates increased to some extent in one or both sections of Laguna Madre during brown tide. The connections between brown tide and any of these species increases may be difficult to extract. Planktivores and detritivores such as menhaden and striped mullet seem not to have benefitted from the dense monoculture of phytoplankton that has formed in an otherwise phytoplankton-sparse ecosystem. Most of the other species are benthic or epibenthic predators, and there does not seem to have been much change in benthic community composition or density nor were there consistent differences between locales in densities of small nekton. Aside from brown shrimp and blue crab, too few fishery species were captured in the present study to test whether abundances differed between Upper Laguna Madre and Lower Laguna Madre.

Conclusions and Recommendations

Shallow submerged dredged material deposits can re-vegetate with seagrasses and attract mobile macrofauna to levels comparable with natural seagrasses within 5 years. Development of comparable benthic communities will take longer, perhaps 5-10 years. Continued use of these placement areas, especially in high maintenance reaches of the GIWW, means that local primary and secondary productivity are continually disrupted at 2-10 year intervals. The effects of these local disruptions on Laguna-wide productivity have yet to be measured. Seagrass acreage in Upper and Lower Laguna Madre was estimated to total 730 km^2 in 1988 (Quammen and Onuf 1993). The total area buried by dredged material at the 6 sites in this study was estimated to be less than 1 km^2, and whether it was all seagrass habitat prior to deposition is unknown. This study indicated that chronic effects of dredged material deposition on floral and faunal standing crops were limited to the immediate vicinity of each deposit and that major recovery was underway after 3 years. Based solely on areal extent, seagrass burial and the subsequent lessening of system-wide productivity would appear to be small. One indicator of system health that needs to be examined for trends is the time series of catch rates for fishery organisms, such as that monitored by Texas Parks and Wildlife Department (McEachron and Fuls 1996). However, such analyses are beyond the scope of this project.

The problem at hand is what to do with dredged material created by maintaining navigation through the Gulf Intracoastal Waterway. Many placement areas are characterized by emergent islands that were formed by the placement of virgin dredged material with a high sand content during construction of the GIWW (Chaney et al. 1978, Morton et al. 1998). Placement of new maintenance materials on these islands would remove material from the system, particularly if containment levees are employed. Continued deposition of maintenance dredged material in shallow submerged sections near these islands could result in placement areas becoming emergent or too shallow to permit seagrass colonization. Since maintenance material has a lower sand content than the original virgin material, shoaling is most likely to occur where deposits are placed in protected areas (e.g., leeward sides of islands) or if subtidal containment structures are employed (Morton et al. 1998). Placement in exposed or deeper waters leads to sediment re-working and transport away from the site of deposit. Shoaling would result in the permanent loss of seagrass beds and fishery productivity, albeit in exchange for intertidal flats, low islands, or uplands which might benefit other organisms such as algae or birds.

Use of deep submerged placement areas that are below the depth limits for seagrasses is another option for material placement. However, in areas of strong wind-induced currents and subsequently continuous high turbidity, use of such deep placement areas can result in re-working of materials (Morton et al. 1998) and possible loss of nearby seagrass beds (Onuf 1994). Careful site selection in conjunction with hydrodynamic modeling could locate deep water placement areas where redistribution of dredged materials is minimized. On the other hand, hydrodynamic modeling could also predict sites where deep water placement and local circulation patterns would permit a build-up of dredged material to elevations in the photic zone that would permit seagrass colonization (Rickner 1979).

The only way to ensure permanent protection of the high primary and secondary productivity of seagrass beds in Laguna Madre from the acute and chronic effects of maintenance dredging, while ensuring navigation capability, is to place dredged materials where they can not be redistributed by wind-induced waves and currents. This means that sediments must be removed from the shallow waters of the ecosystem, either by deposition on previously constructed islands or in deep waters remote from seagrasses, through containment at emergent or submerged levee sites within or adjacent to Laguna Madre, or through offshore disposal. These recommendations are not new (Rickner 1979, Onuf 1994). Such actions should also decrease the frequency and severity of maintenance dredging, initiate a long-term decrease in system turbidity and an increase in seagrass acreage, and return ecosystem productivity to a more natural state.

Acknowledgments

The U.S. Army Corps of Engineers Galveston District provided funding for this project as well as assistance from N. McLellan, R. Medina, and T. Roberts. The following scientists in the Fishery Ecology Branch of the NMFS Galveston Laboratory contributed field and laboratory assistance toward the completion of this project: J. Boyd, M. Devora, J. Doerr, C. Henderson, J.

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Table 1.

Results of two-way analyses of variance (ANOVA) of surface sediment characteristics. Factors are Locale (Upper or Lower Laguna Madre: ULM or LLM) and Habitat (Maximum Impact, Minimum Impact, or Natural Seagrass: Max, Min, or Nat). * = $p < 0.05$, ** = $p < 0.01$. N = 90 per month.

	Month	Locale	Habitat	Interaction	Significant Differences	
Organic content	Sep 95	*	-	**	ULM > LLM	
	Apr 96	-	**	**		Max > Min, Nat
	Sep 96	-	*	-		Nat > Max, Min
	May 97	-	-	-		
	Sep 97	-	-	-		
	Apr 98	*	*	-	LLM > ULM	Min, Max > Nat
% Sand	Sep 95	-	**	-		Nat, Min > Max
	Apr 96	-	**	**		Min > Max, Nat
	Sep 96	-	*	-		Min, Max > Nat
	May 97	-	-	**		
	Sep 97	-	-	-		
	Apr 98	*	-	-	ULM > LLM	
% Silt	Sep 95	**	-	-	LLM > ULM	
	Apr 96	**	-	**	LLM > ULM	
	Sep 96	**	-	-	LLM > ULM	
	May 97	*	-	-	LLM > ULM	
	Sep 97	*	-	-	LLM > ULM	
	Apr 98	**	-	-	LLM > ULM	
% Clay	Sep 95	*	**	**	ULM > LLM	Max > Min, Nat
	Apr 96	**	**	**	ULM > LLM	Max > Min, Nat
	Sep 96	-	-	-		
	May 97	*	-	*	ULM > LLM	
	Sep 97	-	-	-		
	Apr 98	-	-	-		

Table 2.

Results of two-way analyses of variance (ANOVA) of water column characteristics. Factors are Locale (Upper or Lower Laguna Madre: ULM or LLM) and Habitat (Maximum Impact, Minimum Impact, or Natural Seagrass: Max, Min, or Nat). * = $p < 0.05$, ** = $p < 0.01$. N = 90 per month. NA = no turbidity data available from LLM.

	Month	Locale	Habitat	Interaction	Significant Differences	
Temperature	Sep 95	-	-	-		
	Apr 96	**	-	**	ULM > LLM	
	Sep 96	**	**	**	ULM > LLM	Nat, Max > Min
	May 97	**	**	**	ULM > LLM	Nat > Max, Min
	Sep 97	*	**	-	ULM > LLM	Nat > Min, Max
	Apr 98	**	-	-	ULM > LLM	
Salinity	Sep 95	**	-	-	ULM > LLM	
	Apr 96	**	-	-	ULM > LLM	
	Sep 96	**	-	*	ULM > LLM	
	May 97	**	-	-	ULM > LLM	
	Sep 97	**	-	-	ULM > LLM	
	Apr 98	-	**	**		Max, Min > Nat
Depth	Sep 95	**	**	**	ULM > LLM	Nat, Min > Max
	Apr 96	**	**	-	ULM > LLM	Nat, Min > Max
	Sep 96	**	**	-	ULM > LLM	Nat > Min, Max
	May 97	**	**	**	ULM > LLM	Nat > Min, Max
	Sep 97	**	*	*	ULM > LLM	Nat >= Max >= Min
	Apr 98	**	-	**	ULM > LLM	
Turbidity	Sep 95	-	**	-		Max > Min, Nat
	Apr 96	NA	**	NA		Max > Min, Nat
	Sep 96	-	-	-		
	May 97	**	-	**	LLM > ULM	
	Sep 97	*	-	-	ULM > LLM	
	Apr 98	-	-	-		

Table 3.

Results of two-way analyses of variance (ANOVA) of seagrass community characteristics. Factors are Locale (Upper or Lower Laguna Madre: ULM or LLM) and Habitat (Maximum Impact, Minimum Impact, or Natural Seagrass: Max, Min, or Nat). * = $p < 0.05$, ** = $p < 0.01$. N = 71-90 per month. Root = root + rhizome. RSR = root : shoot ratio.

	Month	Locale	Habitat	Interaction	Significant Differences	
Seagrass cover	Sep 95	-	**	-		Nat > Min > Max
	Apr 96	**	**	-	ULM > LLM	Nat > Min > Max
	Sep 96	-	**	-		Nat > Min > Max
	May 97	-	**	**		Nat, Min > Max
	Sep 97	*	**	*	LLM > ULM	Nat, Min > Max
	Apr 98	*	**	*	LLM > ULM	Nat, Min > Max
Shoot biomass	Sep 95	-	**	-		Nat, Min > Max
	Apr 96	-	**	-		Nat > Min > Max
	Sep 96	*	**	*	ULM > LLM	Nat > Min > Max
	May 97	**	**	**	ULM > LLM	Nat > Min > Max
	Sep 97	-	**	*		Nat, Min > Max
	Apr 98	-	**	*		Nat > Min > Max
Root biomass	Sep 95	-	**	-		Nat, Min > Max
	Apr 96	**	**	-	LLM > ULM	Nat > Min > Max
	Sep 96	*	**	*	ULM > LLM	Nat > Min > Max
	May 97	**	**	**	ULM > LLM	Nat > Min > Max
	Sep 97	-	**	*		Nat, Min > Max
	Apr 98	-	**	-		Nat, Min > Max
RSR	Sep 95	**	**	*	LLM > ULM	Nat, Min > Max
	Apr 96	*	**	*	LLM > ULM	Nat > Min > Max
	Sep 96	-	**	-		Nat, Min > Max
	May 97	**	**	**	LLM > ULM	Nat, Min > Max
	Sep 97	-	**	**		Nat, Min > Max
	Apr 98	*	-	-	LLM > ULM	

Table 4.

Species composition of seagrasses found at each site and habitat (presence indicated by +). Max = Maximum impact, Min = Minimum impact, Nat = Natural seagrass.

		Placement Area																	
		187			194			197			211			221			222		
Species	Month	Max	Min	Nat	Max	Min	Nat	Max	Min	Nat	Max	Min	Nat	Max	Min	Nat	Max	Min	Nat
Halodule wrightii	Sep 95		+	+		+	+		+	+		+	+		+	+		+	+
	Apr 96	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+	+
	Sep 96	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+	+
	May 97	+		+		+	+			+	+	+	+	+	+	+	+	+	+
	Sep 97	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+	
	Apr 98	+	+	+	+		+		+	+	+	+	+	+	+	+	+	+	
Halophila engelmannii	Sep 95							+		+									
	Apr 96				+			+	+	+									
	Sep 96		+						+				+			+			
	May 97		+			+											+	+	
	Sep 97					+									+	+		+	
	Apr 98				+	+		+	+	+	+				+	+	+	+	
Ruppia maritima	Sep 95																		
	Apr 96																		
	Sep 96																		
	May 97		+		+	+			+									+	
	Sep 97	+	+	+		+						+							
	Apr 98			+		+	+		+			+	+				+		

Table 4 (continued)

Syringodium filiforme	Sep 95						+
	Apr 96		+	+	+	+	+
	Sep 96			+		+	+
	May 97						+
	Sep 97			+		+	+
	Apr 98	+		+	+	+	+
Thalassia testudinum	Sep 95						
	Apr 96					+	
	Sep 96						
	May 97						+
	Sep 97						+
	Apr 98				+		

Table 5.

Results of two-way analyses of variance (ANOVA) of major benthic groups (Annelids = A, non-decapod Crustaceans = C, Molluscs = M) and dominant taxa (the 20 most abundant taxa overall during months when they comprised the top 70% of the total fauna for that month), arranged in descending order of abundance. Locale = Upper or Lower Laguna Madre (ULM or LLM), Habitat = Maximum Impact, Minimum Impact, or Natural Seagrass (Max, Min, or Nat). * = $p < 0.05$, ** = $p < 0.01$.

			ANOVA results				
	Date	N	Locale	Habitat	L x H	Significant Differences	
Annelids	Sep 95	6352	-	**	**		Nat, Min > Max
	Apr 96	7940	-	*	-		Nat, Min > Max
	Sep 96	8152	**	**	-	LLM > ULM	Nat, Min > Max
	May 97	5364	-	**	**		Nat > Min > Max
	Sep 97	8291	**	**	**	LLM > ULM	Nat, Min > Max
	Apr 98	9580	**	**	-	LLM > ULM	Nat > Min, Max
Crustaceans	Sep 95	6194	*	**	-	ULM > LLM	Min > Nat, Max
	Apr 96	5827	-	*	*		Nat, Min > Max
	Sep 96	1370	**	**	-	LLM > ULM	Min > Nat, Max
	May 97	1550	*	**	-	ULM > LLM	Min, Nat > Max
	Sep 97	1783	-	**	-		Nat, Min > Max
	Apr 98	9234	**	**	-	ULM > LLM	Nat, Min > Max
Molluscs	Sep 95	428	-	-	-		
	Apr 96	956	**	-	*	ULM > LLM	
	Sep 96	351	-	**	**		Max, Min > Nat
	May 97	1075	**	-	-	ULM > LLM	
	Sep 97	932	**	-	-	ULM > LLM	
	Apr 98	882	**	-	-	ULM > LLM	
Cerapus benthophilus (C)	Sep 95	4632	**	**	**	ULM > LLM	Min > Nat, Max
	Apr 96	1292	**	**	**	ULM > LLM	Min > Nat, Max
	May 97	381	*	**	*	ULM > LLM	Min > Nat, Max
	Sep 97	401	-	*	-		Nat, Min > Max
	Apr 98	6870	**	**	-	ULM > LLM	Nat, Min > Max
Prionospio heterobranchia (A)	Sep 95	944	-	**	-		Nat, Min > Max
	Apr 96	1235	**	-	-	ULM > LLM	
	Sep 96	1847	**	**	-	LLM > ULM	Min > Nat > Max
	May 97	574	-	**	*		Nat, Min > Max
	Sep 97	2159	*	**	*	LLM > ULM	Nat, Min > Max
	Apr 98	1313	**	**	*	LLM > ULM	Nat, Min > Max
Streblospio benedicti (A)	Sep 95	1070	**	-	-	LLM > ULM	
	Apr 96	2006	**	**	**	LLM > ULM	Nat, Max > Min
	Sep 96	1175	-	-	-		
	May 97	577	**	**	**	LLM > ULM	Nat > Min, Max
	Sep 97	675	*	*	**	LLM > ULM	Nat > Min, Max
	Apr 98	2153	**	-	-	LLM > ULM	
Oligochaetes (A)	Sep 95	2033	**	**	**	ULM > LLM	Nat, Min > Max
	Apr 96	2144	-	**	**		Nat, Min > Max
	Sep 96	973	-	**	-		Nat > Min > Max
	May 97	1033	-	**	-		Nat, Min > Max
	Sep 97	1004	-	**	-		Nat > Min, Max
	Apr 98	481	-	**	-		Nat > Min, Max

Table 5 (continued)

Ampelisca spp. (C)	Apr 96	2590	**	-	**	LLM > ULM	
	May 97	424	**	**	*	LLM > ULM	Min > Nat, Max
	Sep 97	250	**	**	-	LLM > ULM	Min > Nat, Max
	Apr 98	1361	**	*	-	LLM > ULM	Min > Nat, Max
Capitella capitata (A)	Sep 95	476	-	-	-		
	Apr 96	579	-	-	-		
	Sep 96	313	**	-	-	LLM > ULM	
	May 97	544	-	**	-		Nat > Min, Max
	Sep 97	548	-	-	*		Nat > Min > Max
	Apr 98	312	**	*	-	LLM > ULM	Nat > Min, Max
Syllis cornuta (A)	Sep 95	565	-	**	-		Nat > Min > Max
	Apr 96	479	-	**	-		Nat > Min, Max
	Sep 96	689	-	**	**		Nat, Min > Max
	May 97	238	**	**	**	ULM > LLM	Nat, Min > Max
	Sep 97	789	-	**	-		Nat, Min > Max
Grandidierella bonnieroides (C)	Sep 95	428	**	-	-	ULM > LLM	
	Apr 96	548	-	*	**		Nat > Min > Max
	Sep 96	543	-	**	-		Min, Nat > Max
	May 97	254	**	-	-	ULM > LLM	
	Sep 97	301	-	**	-		Nat, Min > Max
Anomalocardia aubergiana (M)	Sep 96	241	-	**	**		Max, Min > Nat
	May 97	762	**	-	-	ULM > LLM	
	Sep 97	497	**	-	-	ULM > LLM	
	Apr 98	286	-	-	-		
Exogone dispar (A)	Sep 95	423	**	**	**	ULM > LLM	Min > Nat, Max
	Sep 97	689	-	*	-		Nat, Min > Max
	Apr 98	259	-	-	-		
Chone cf. americana (A)	Apr 96	828	**	-	-	ULM > LLM	
	May 97	232	-	**	-		Nat, Min > Max
	Sep 97	279	-	**	**		Nat, Min > Max
	Apr 98	592	**	**	**	LLM > ULM	Nat, Min > Max
Hydroides dianthus (A)	Sep 96	1403	**	**	**	LLM > ULM	Nat > Min, Max
Melinna maculata (A)	May 97	292	**	-	-	LLM > ULM	
	Apr 98	635	**	-	-	LLM > ULM	
Heteromastus filiformis (A)	Sep 96	239	**	-	-	LLM > ULM	
	May 97	160	**	-	-	LLM > ULM	
	Apr 98	539	**	-	-	LLM > ULM	
Polydora ligni (A)	Sep 96	812	-	-	-		
Sabaco elongatus (A)	Apr 98	295	**	*	-	ULM > LLM	Max > Nat, Min
Mulinia lateralis (M)	Apr 96	591	**	-	*	LLM > ULM	
	May 97	199	-	-	-		
Nameris bicornis (A)	May 97	616	**	**	**	ULM > LLM	Nat > Min, Max
Polydora socialis (A)	Sep 97	577	*	-	*	LLM > ULM	Max, Min > Nat
Erichsonella attenuata (C)	Sep 95	233	**	**	**	ULM > LLM	Nat, Min > Max
	Sep 97	214	**	**	**	ULM > LLM	Nat, Min > Max

Table 6.

Densities (number per core) of annelids, non-decapod crustaceans, molluscs, and the 11 most abundant taxa (>70% of all organisms collected) by month and habitat. Max =Maximum Impact, Min = Minimum Impact, Nat = Natural Seagrass. N = 30 per habitat per month, except n = 29 for May 97 Min and Sep 97 Min, and n = 27 for Sep 97 Nat.

		Sep 95		Apr 96		Sep 96		May 97		Sep 97		Apr 98	
Taxon	Habitat	mean	se	mean	se	mean	se	mean	se	mean	se	mean	se
Annelids	Max	33.6	5.9	61.9	13.2	45.7	7.7	15.0	3.1	25.4	6.0	74.8	16.1
	Min	81.6	9.1	88.9	19.2	97.7	18.4	48.7	6.6	132.2	22.9	97.2	19.9
	Nat	96.5	12.4	113.8	22.8	128.3	24.9	117.5	17.4	136.8	16.2	147.3	17.5
Prionospio heterobranchia	Max	3.6	1.2	6.5	2.2	5.0	1.3	0.7	0.4	5.8	2.1	4.1	1.4
	Min	15.3	2.3	14.0	4.4	35.2	12.1	6.9	2.8	35.7	8.0	13.8	4.2
	Nat	12.6	2.3	16.1	4.7	21.9	6.4	12.0	3.5	35.3	4.4	25.9	6.1
Streblospio benedicti	Max	12.1	3.9	11.9	4.3	12.5	2.9	0.5	0.2	2.0	0.9	20.2	11.4
	Min	10.4	3.5	15.9	14.2	11.4	3.8	2.7	1.3	6.6	5.4	21.3	9.1
	Nat	13.2	3.5	39.0	18.0	15.8	5.9	16.5	5.3	15.7	4.9	30.3	12.1
Oligochaeta	Max	2.6	1.0	3.9	0.8	3.2	0.8	1.7	1.0	1.3	0.5	1.7	0.4
	Min	25.1	5.7	23.1	4.5	6.9	1.5	10.4	3.3	13.5	10.1	3.1	0.8
	Nat	40.1	12.5	24.9	7.8	23.1	6.0	23.1	8.6	21.2	7.4	11.3	3.3
Capitella capitata	Max	4.0	1.0	6.5	1.3	3.6	0.6	1.5	0.4	3.7	1.3	2.2	0.8
	Min	4.8	1.6	6.7	1.7	4.3	1.3	3.0	0.8	4.9	1.4	3.6	1.3
	Nat	7.0	1.5	4.0	0.6	2.8	0.6	14.1	3.4	10.9	3.2	4.6	1.0
Syllis cornuta	Max	0.5	0.2	3.7	1.4	2.0	0.7	0.1	0.1	0.8	0.3	0.0	0.0
	Min	4.9	2.8	2.7	0.8	10.2	2.2	3.7	1.0	16.0	3.8	0.0	0.0
	Nat	13.5	3.0	8.3	2.2	10.8	1.7	4.4	1.4	11.1	2.5	0.0	0.0

Table 6 (continued)

Exogone dispar	Max	1.7	1.1	0.4	0.2	0.0	0.0	0.2	0.1	2.5	1.7	2.0	0.6
	Min	10.3	2.2	7.4	2.5	0.3	0.2	0.8	0.4	14.1	4.3	3.0	0.6
	Nat	2.0	0.5	3.9	1.0	0.3	0.1	2.5	1.4	13.1	5.7	3.6	0.7
Chone cf. americana	Max	1.9	0.6	5.7	2.7	0.2	0.1	0.8	0.6	0.8	0.4	0.9	0.4
	Min	1.5	0.3	5.5	1.4	0.8	0.3	2.4	0.8	2.0	0.5	5.1	1.0
	Nat	1.7	0.4	8.1	1.9	2.4	0.9	4.9	1.6	7.3	1.9	13.7	4.5
Crustaceans	Max	19.3	5.1	61.1	18.2	10.3	2.6	8.3	2.9	3.1	0.8	25.2	8.0
	Min	165.8	80.5	66.8	14.4	26.3	5.2	28.7	6.6	25.8	5.0	143.7	34.6
	Nat	21.4	3.6	66.3	12.7	9.1	1.7	15.9	3.2	34.9	11.9	138.9	52.9
Cerapus benthophilus	Max	2.7	1.4	6.8	3.0	0.2	0.2	0.6	0.4	0.0	0.0	17.1	7.3
	Min	147.4	79.9	22.9	8.9	6.5	3.6	12.2	6.0	2.9	1.7	100.0	32.3
	Nat	4.3	1.2	8.4	2.9	0.1	0.1	0.3	0.2	11.7	9.3	111.8	51.7
Ampelisca spp.	Max	8.9	3.1	42.1	12.6	1.0	0.3	4.6	2.6	0.7	0.3	3.3	1.1
	Min	1.5	0.3	26.4	10.6	2.4	1.0	8.4	2.7	5.8	2.4	29.1	14.3
	Nat	0.7	0.2	37.2	10.6	0.9	0.2	1.8	0.5	2.3	0.7	12.9	4.3
Grandidierella bonnieroides	Max	4.6	1.4	4.5	1.7	3.6	1.0	0.7	0.2	0.7	0.3	0.9	0.3
	Min	4.7	1.0	7.7	3.3	10.0	1.7	2.4	0.6	4.5	1.1	1.3	0.4
	Nat	4.9	1.8	5.7	1.1	4.6	0.7	5.5	2.6	5.6	1.4	1.2	0.4
Molluscs	Max	3.8	0.8	11.9	3.3	4.6	0.7	15.7	4.1	8.5	1.5	9.4	1.8
	Min	8.5	5.8	8.7	1.4	4.1	0.6	11.3	2.6	14.6	2.9	9.6	1.8
	Nat	2.0	0.5	11.3	2.7	3.0	1.1	9.3	2.2	9.4	2.6	10.5	2.1
Anomalocardia auberziana	Max	1.4	0.4	3.8	1.0	3.6	0.6	11.6	3.6	6.5	1.5	2.8	0.6
	Min	0.5	0.2	2.5	0.7	2.4	0.4	7.4	2.2	5.8	2.0	2.5	0.6
	Nat	0.9	0.3	1.4	0.5	2.0	0.9	6.6	2.1	5.0	1.8	4.3	1.4

Table 7.

Results of two-way analyses of variance (ANOVA) of total fishes, total decapods, and 15 dominant species (during months when they comprised the top 80% of the fauna captured that month), arranged in decreasing order of abundance. Locale = Upper or Lower Laguna Madre (ULM or LLM), Habitat = Maximum Impact, *Minimum* Impact, or Natural Seagrass (Max, Min, or Nat). * = $p < 0.05$, ** = $p < 0.01$.

			ANOVA results				
	Date	N	Locale	Habitat	L x H	Significant Differences	
Fishes	Sep 95	945	-	**	**		Nat, Min > Max
	Apr 96	1150	**	**	*	LLM > ULM	Nat > Min > Max
	Sep 96	820	*	**	-	LLM > ULM	Nat, Min > Max
	May 97	1012	-	**	**		Max > Nat, Min
	Sep 97	734	*	**	-	LLM > ULM	Nat, Min > Max
	Apr 98	687	*	**	*	ULM > LLM	Nat > Min > Max
Decapods	Sep 95	3334	**	**	**	LLM > ULM	Nat, Min > Max
	Apr 96	2242	-	**	-		Nat, Min > Max
	Sep 96	3210	**	**	-	LLM > ULM	Nat, Min > Max
	May 97	1460	-	**	**		Nat > Min > Max
	Sep 97	2812	-	**	**		Nat, Min > Max
	Apr 98	2166	-	**	-		Nat, Min > Max
Palaemonetes intermedius	Sep 95	1010	**	**	**	ULM > LLM	Nat, Min > Max
	Apr 96	1065	**	**	**	ULM > LLM	Nat, Min > Max
	Sep 96	1176	**	**	**	ULM > LLM	Nat > Min > Max
	May 97	816	**	**	**	ULM > LLM	Nat > Min > Max
	Sep 97	964	**	**	**	ULM > LLM	Nat, Min > Max
	Apr 98	410	-	**	-		Nat > Min, Max
Hippolyte zostericola	Sep 95	616	**	**	**	LLM > ULM	Nat, Min > Max
	Apr 96	165	**	**	-	LLM > ULM	Nat, Min > Max
	Sep 96	399	**	**	**	LLM > ULM	Nat, Min > Max
	Sep 97	846	-	**	-		Nat, Min > Max
	Apr 98	676	**	**	-	ULM > LLM	Nat, Min > Max
Dyspanopeus texanus	Sep 95	237	**	**	**	ULM > LLM	Nat > Min > Max
	Apr 96	175	-	**	-		Nat, Min > Max
	Sep 96	382	**	**	*	LLM > ULM	Nat, Min > Max
	May 97	167	**	**	**	ULM > LLM	Nat > Min > Max
	Sep 97	442	-	**	**		Min > Nat > Max
	Apr 98	402	*	-	-	ULM > LLM	
Gobiosoma robustum	Sep 95	239	**	**	**	LLM > ULM	Nat, Min > Max
	Sep 96	470	**	**	*	LLM > ULM	Nat, Min > Max
	May 97	99	-	**	-		Nat, Min > Max
	Sep 97	515	**	**	-	LLM > ULM	Nat, Min > Max
	Apr 98	329	*	**	*	LLM > ULM	Nat, Min > Max

Table 7 (continued)

Farfantepenaeus aztecus	Sep 95	235	**	**	**	LLM > ULM	Nat, Min > Max
	Apr 96	398	**	**	**	LLM > ULM	Nat, Min > Max
	Sep 96	104	**	**	**	LLM > ULM	Nat > Min > Max
	May 97	236	**	**	**	LLM > ULM	Nat, Min > Max
	Sep 97	149	**	*	-	LLM > ULM	Nat, Min > Max
	Apr 98	221	**	-	-	ULM > LLM	
Lagodon rhomboides	Apr 96	803	**	**	**	LLM > ULM	Nat > Min > Max
	May 97	95	-	**	-		Nat, Min > Max
	Apr 98	102	-	**	-		Nat > Min, Max
Tozeuma carolinense	Sep 95	532	**	**	-	LLM > ULM	Nat, Min > Max
	Sep 96	163	-	*	-		Nat, Min > Max
Brevoortia patronus	Apr 96	175	-	-	-		
	May 97	615	**	-	**	LLM > ULM	
Palaemonetes pugio	Sep 95	404	-	**	**		Nat > Min > Max
	Sep 96	190	-	*	-		Nat, Min > Max
	Sep 97	83	-	*	-		Nat, Min > Max
Syngnathus scovelli	Sep 95	177	-	**	**		Min > Nat > Max
	Sep 96	94	-	**	-		Nat, Min > Max
	May 97	74	**	**	**	ULM > LLM	Nat, Min > Max
	Sep 97	87	-	**	-		Nat, Min > Max
Anchoa mitchilli	Sep 95	355	**	-	-	ULM > LLM	
Callinectes sapidus	Sep 95	94	**	**	**	LLM > ULM	Min > Nat, Max
	Apr 96	153	**	**	**	LLM > ULM	Nat, Min > Max
	Sep 97	37	**	-	-	LLM > ULM	
	Apr 98	116	**	*	*	LLM > ULM	Nat > Min > Max
Panopeus turgidus	Sep 96	334	-	*	-		Nat, Min > Max
Alpheus heterochaelis	Sep 95	129	-	**	-		Nat, Min > Max
	Sep 97	115	**	**	**	ULM > LLM	Min > Nat > Max
Pagurus criniticornis	Sep 96	230	*	-	-	LLM > ULM	

Table 8.

Densities (number per sq. m) of total fishes, total decapods, and the 15 most abundant taxa (>93% of all organisms collected) by month and habitat. Max = Maximum Impact, Min = Minimum Impact, Nat = Natural Seagrass. N = 30 per habitat per month.

		Sep 95		Apr 96		Sep 96		May 97		Sep 97		Apr 98	
Taxon	Habitat	mean	se	mean	se	mean	se	mean	se	mean	se	mean	se
Fishes	Max	3.1	1.0	1.3	0.4	1.1	0.4	17.8	10.0	2.6	0.8	4.8	1.1
	Min	17.3	4.7	18.0	7.0	14.1	3.6	8.9	2.8	13.1	1.6	8.5	1.4
	Nat	11.2	1.7	18.9	3.4	12.1	1.9	7.1	0.8	8.8	1.0	9.6	1.2
Anchoa mitchilli	Max	2.1	0.9	0.1	0.1	0.4	0.3	0.0	0.0	0.0	0.0	0.5	0.2
	Min	7.5	4.3	0.3	0.2	1.4	0.9	0.2	0.1	0.0	0.0	0.5	0.3
	Nat	2.3	1.0	0.0	0.0	0.9	0.5	0.6	0.3	0.0	0.0	0.2	0.1
Brevoortia patronus	Max	0.0	0.0	0.6	0.3	0.0	0.0	16.5	10.0	0.0	0.0	1.2	0.7
	Min	0.0	0.0	4.1	2.5	0.0	0.0	3.7	2.6	0.0	0.0	0.3	0.1
	Nat	0.0	0.0	1.1	0.9	0.1	0.1	0.3	0.2	0.0	0.0	0.1	0.1
Gobiosoma robustum	Max	0.2	0.1	0.0	0.0	0.2	0.1	0.0	0.0	1.9	0.7	2.1	0.9
	Min	3.8	0.7	0.5	0.2	9.2	3.1	1.5	0.4	9.5	1.5	3.9	0.8
	Nat	4.4	1.1	0.3	0.1	6.3	1.5	1.8	0.4	5.8	0.9	4.9	0.8
Lagodon rhomboides	Max	0.0	0.0	0.1	0.0	0.0	0.0	0.4	0.2	0.1	0.1	0.3	0.1
	Min	0.2	0.1	11.3	6.3	0.3	0.1	1.4	0.3	0.4	0.1	0.4	0.1
	Nat	0.1	0.0	15.4	3.4	0.6	0.2	1.4	0.4	0.2	0.1	2.7	0.8
Syngnathus scovelli	Max	0.1	0.1	0.0	0.0	0.2	0.1	0.0	0.0	0.1	0.0	0.2	0.1
	Min	3.6	0.5	0.4	0.1	1.4	0.4	1.0	0.3	1.7	0.4	1.2	0.2
	Nat	2.2	0.4	0.6	0.2	1.6	0.2	1.4	0.4	1.1	0.2	1.1	0.3

Table 8 (continued)

Decapods	Max	2.4	0.6	2.7	0.6	1.9	0.8	1.3	0.4	3.3	1.0	15.1	5.8
	Min	53.3	5.7	39.0	7.7	61.4	17.9	19.5	3.2	57.5	11.1	25.0	5.0
	Nat	57.4	8.8	33.2	2.6	43.7	6.0	27.8	3.8	33.0	4.1	32.1	5.5
Alpheus heterochaelis	Max	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0
	Min	2.8	0.7	0.1	0.1	1.3	0.5	0.0	0.0	3.0	0.8	0.1	0.0
	Nat	1.5	0.4	0.2	0.1	1.4	0.4	0.1	0.1	0.8	0.3	0.3	0.2
Callinectes sapidus	Max	0.2	0.1	0.3	0.1	0.2	0.1	0.0	0.0	0.3	0.2	0.8	0.4
	Min	2.1	0.5	2.7	0.8	1.2	0.5	0.6	0.2	0.5	0.2	1.4	0.5
	Nat	0.8	0.3	2.1	0.5	1.0	0.4	0.3	0.1	0.4	0.2	1.7	0.4
Dyspanopeus texanus	Max	0.3	0.1	0.0	0.0	0.3	0.3	0.0	0.0	0.5	0.2	6.4	3.3
	Min	3.5	0.8	3.1	1.8	6.3	2.7	1.7	0.7	11.2	5.8	3.7	1.5
	Nat	5.9	1.3	2.7	0.6	6.1	3.3	3.9	1.4	3.0	0.7	3.2	0.7
Farfantepenaeus aztecus	Max	0.6	0.3	1.1	0.3	0.0	0.0	0.6	0.2	1.0	0.5	1.5	0.5
	Min	4.0	0.7	5.0	0.8	1.4	0.5	4.0	1.0	2.1	0.5	3.3	0.8
	Nat	3.3	0.7	7.2	1.2	2.1	0.4	3.2	0.8	1.9	0.5	2.5	0.6
Hippolyte zostericola	Max	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	4.7	2.3
	Min	11.6	4.0	3.4	1.2	8.0	3.1	0.7	0.3	17.6	5.2	11.2	2.8
	Nat	8.8	3.4	2.1	0.5	5.3	1.9	0.0	0.0	10.4	2.7	6.7	1.8
Pagurus criniticornis	Max	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.0
	Min	0.1	0.1	0.9	0.5	7.5	7.2	0.1	0.1	0.5	0.3	0.2	0.1
	Nat	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Palaemonetes intermedius	Max	0.0	0.0	0.0	0.0	0.9	0.6	0.0	0.0	0.6	0.4	0.6	0.3
	Min	16.9	2.8	19.4	5.3	18.7	6.4	8.7	2.1	17.1	3.5	2.5	0.9
	Nat	16.1	2.8	16.1	3.2	19.7	2.4	18.5	3.8	14.4	2.1	10.6	2.7

Table 8 (continued)

Palaemonetes pugio	Max	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Min	2.9	0.7	0.8	0.2	3.4	1.5	0.2	0.1	1.7	0.8	0.1	0.0
	Nat	10.4	2.8	0.7	0.2	3.0	1.2	0.5	0.2	1.0	0.4	1.2	0.4
Panopeus turgidus	Max	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0	0.0
	Min	0.0	0.0	0.0	0.0	8.4	5.9	0.1	0.1	0.0	0.0	0.0	0.0
	Nat	0.0	0.0	0.0	0.0	2.7	1.1	0.3	0.2	0.0	0.0	0.0	0.0
Tozeuma carolinense	Max	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Min	8.1	3.1	1.9	0.8	4.3	2.2	2.1	1.2	2.2	1.1	0.7	0.4
	Nat	9.3	4.0	0.4	0.2	1.1	0.4	0.1	0.0	0.2	0.1	0.4	0.2

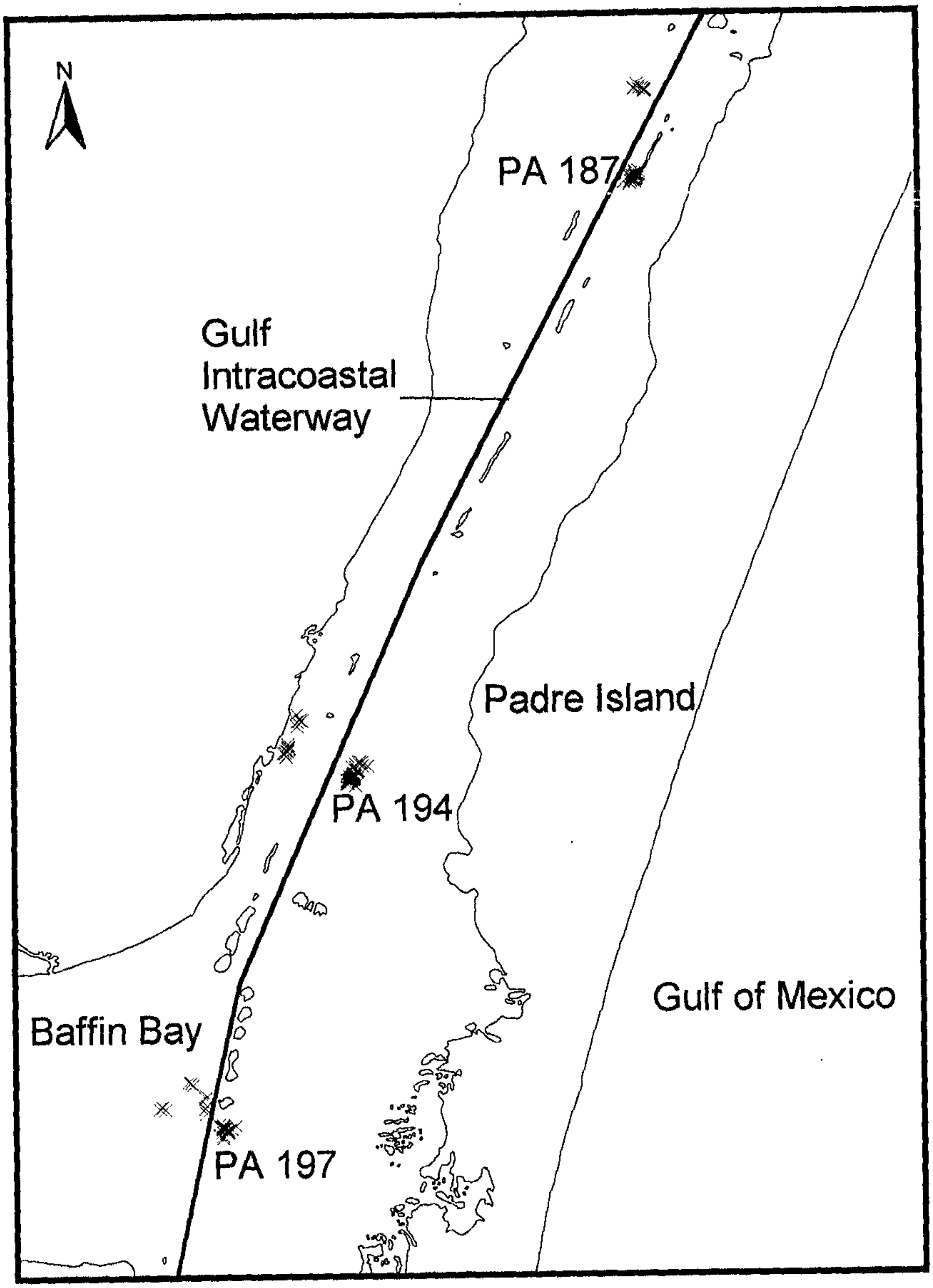
Table 9.

Trends in sediments, seagrass, water, benthos, and macrofauna over time in seagrass habitats at Placement Area 194 relative to distance from the dredged material. Samples were taken 1-5 m (= M1), 10-15 m (= M10), 100-105 m (= M100), and 1000+ m (= Nat) from non-vegetated mud. Listed habitats had significantly higher values (ANOVA, $p < 0.05$) than unlisted habitats. Only the most abundant species (comprising the top 70% of the fauna in a given month) were tested. Dash (-) = no significant difference or not abundant enough to be tested. Note that due to small sample size (5 per habitat per month), ANOVA power is low.

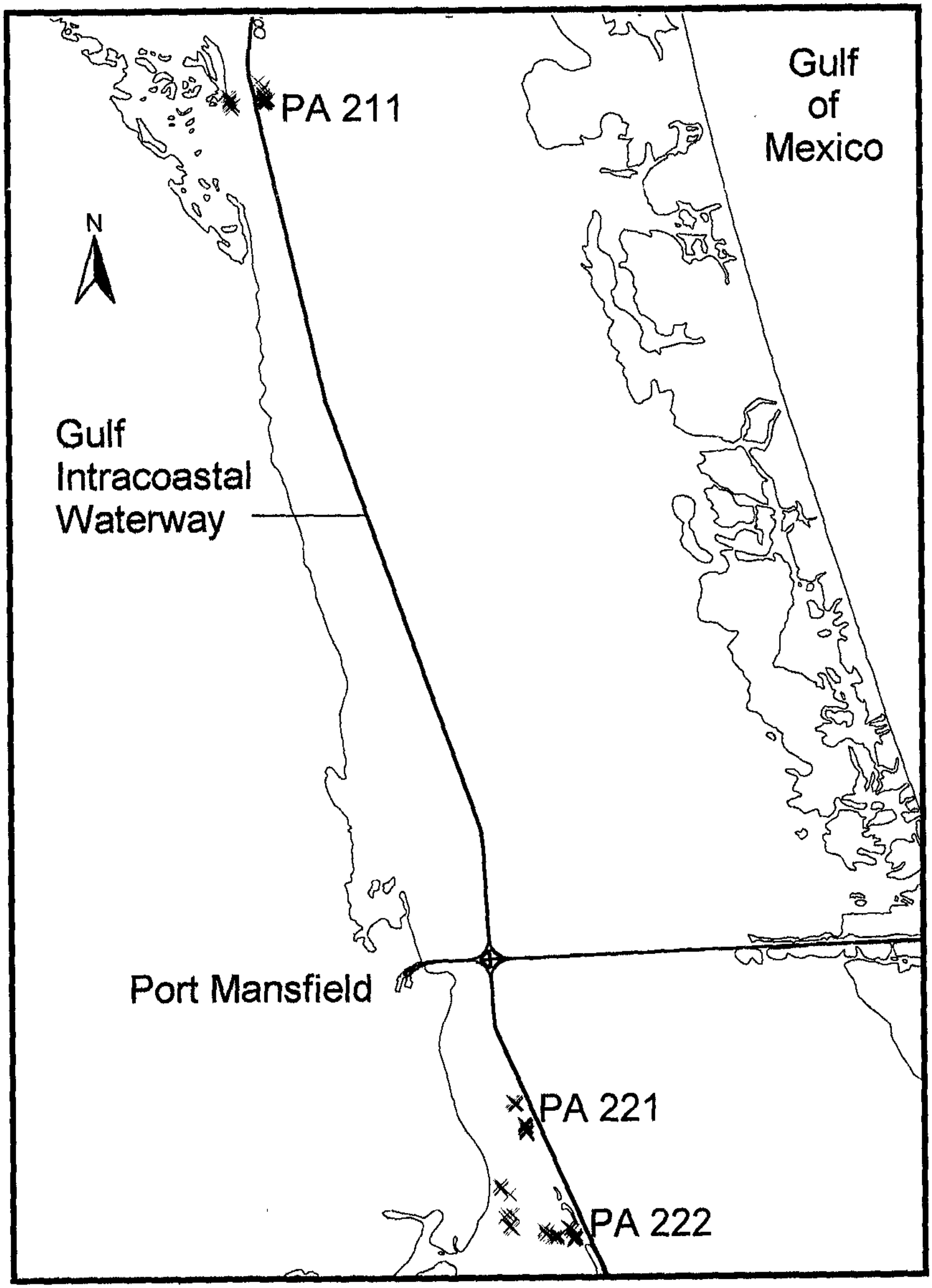
Component	Characteristic	Sep 95	Apr 96	Sep 96	May 97	Sep 97	Apr 98
Surface sediments	Organic content	-	Nat	Nat	-	-	M1
	% Sand	-	-	M1, M10, M100	-	-	M10, M100
	% Silt	M1	-	Nat	-	-	-
	% Clay	-	-	Nat	-	-	-
Water column	Turbidity	-	Nat	M1	M1	-	Nat
	Temperature	Nat, M100	M1	-	M1, M10, M100	Nat, M10, M100	Nat
	Salinity	-	Nat, M10, M100	-	M1, M10	Nat, M1, M10	M1, M10, M100
	Depth	Nat	Nat, M100	-	-	-	M100
Seagrass	Coverage	-	-	Nat	-	-	Nat, M100
	Shoot biomass	-	Nat, M10, M100	Nat, M100	Nat	Nat, M10, M100	M10
	Root biomass	-	Nat, M10, M100	Nat, M100	Nat	Nat, M10, M100	Nat
	RSR	-	-	M10	-	Nat, M10, M100	M100
Benthos	Annelids	-	-	-	Nat, M10, M100	Nat, M1, M100	-
	Capitella capitata	-	-	Nat	-	M1	-
	Chone cf. americana	-	M10, M100	-	-	-	-
	Exogone dispar	-	-	-	-	-	-
	Mediomastus ambiseta	-	-	-	-	-	-
	Mediomastus sp	-	-	-	-	-	M1, M10, M100
	Naineris bicornis	-	-	-	Nat	-	-
	Naineris dendritica	-	-	-	-	-	Nat
	Oligochaetes	-	-	-	Nat, M100	Nat	-
	Polydora ligni	-	-	-	-	-	-
	Prionospio heterobranchia	-	Nat	-	Nat, M100	Nat, M1, M100	Nat
	Sabaco elongatus	-	-	M1	-	-	-
	Streblospio benedicti	-	-	-	-	-	-
	Syllis cornuta	M10, M100	-	-	Nat	Nat, M10, M100	-
	Syllis lutea	-	-	-	-	-	-
	Trypanosyllis vittigera	-	-	Nat	Nat, M100	Nat	-

Table 9 (continued)

	Non-decapod Crustaceans	Min	-	-	-	Nat, M10, M100	-
	Ampelisca spp.	-	-	-	-	-	-
	Cerapus benthophilus	-	-	-	-	M1, M10, M100	-
	Erichsonella attenuata	-	-	-	Nat	Nat, M100	-
	Gammarus mucronatus	-	-	-	-	-	-
	Grandidierella bonnieroides	-	-	-	M100	-	-
	Molluscs	-	-	-	-	-	-
	Amygdalum papyria	-	-	-	-	M1	-
	Anomalocardia aubergiana	-	-	-	-	-	-
	Mulinia lateralis	-	-	-	-	-	-
Macrofauna	Fishes	-	-	-	-	M1, M10, M100	-
	Anchoa mitchilli	-	-	Nat, M100	-	-	-
	Brevoortia patronus	-	-	-	-	-	-
	Gobiosoma robustum	-	-	-	-	M1, M10, M100	-
	Lagodon rhomboides	-	-	-	-	-	-
	Menidia beryllina	-	-	Nat, M100	-	-	-
	Syngnathus scovelli	M1, M10, M100	-	-	-	-	-
	Decapods	-	M10, M100	-	Nat	M1, M10, M100	-
	Alpheus heterochaelis	-	-	-	-	M10	-
	Dyspanopeus texana	-	-	-	-	-	Nat
	Farfantepenaeus aztecus	-	-	-	-	-	-
	Hippolyte zostericola	-	-	-	-	M1, M10, M100	-
	Palaemonetes intermedius	M1, M10, M100	M100	-	Nat	-	-
	Palaemonetes pugio	-	M1, M10, M100	-	-	-	-
	Palaemonetes vulgaris	-	-	-	-	-	-



Map 1. Placement Areas (PA) and sampling sites (X) in Upper Laguna Madre



Map 2. Placement Areas (PA) and sampling sites (X) in Lower Laguna Madre

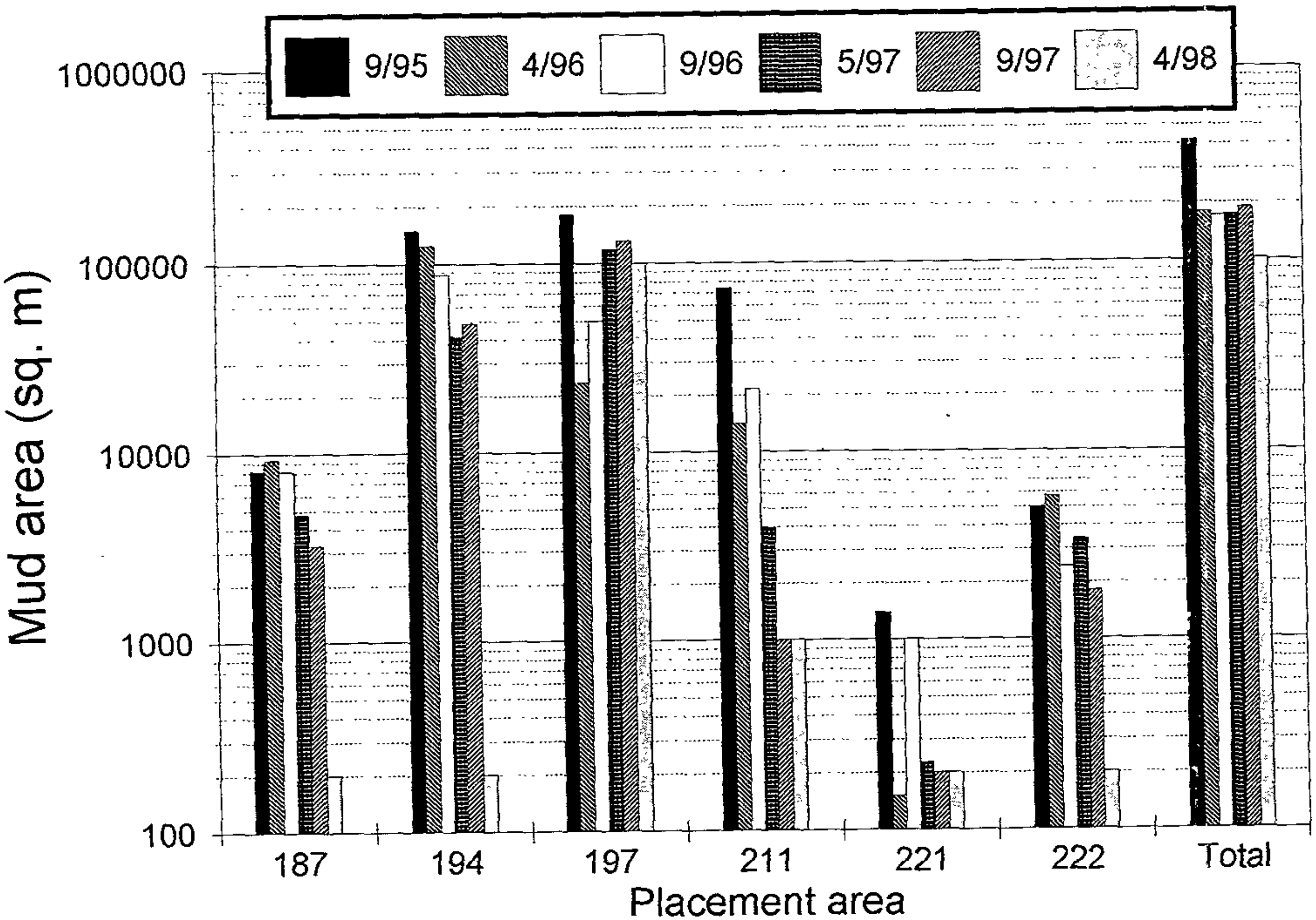


Figure 1. Estimated area of non-vegetated mud remaining at each site after dredged material placement during January 1995 (Upper Laguna Madre, areas187-197) and March 1995 (Lower Laguna Madre, areas 211-222).

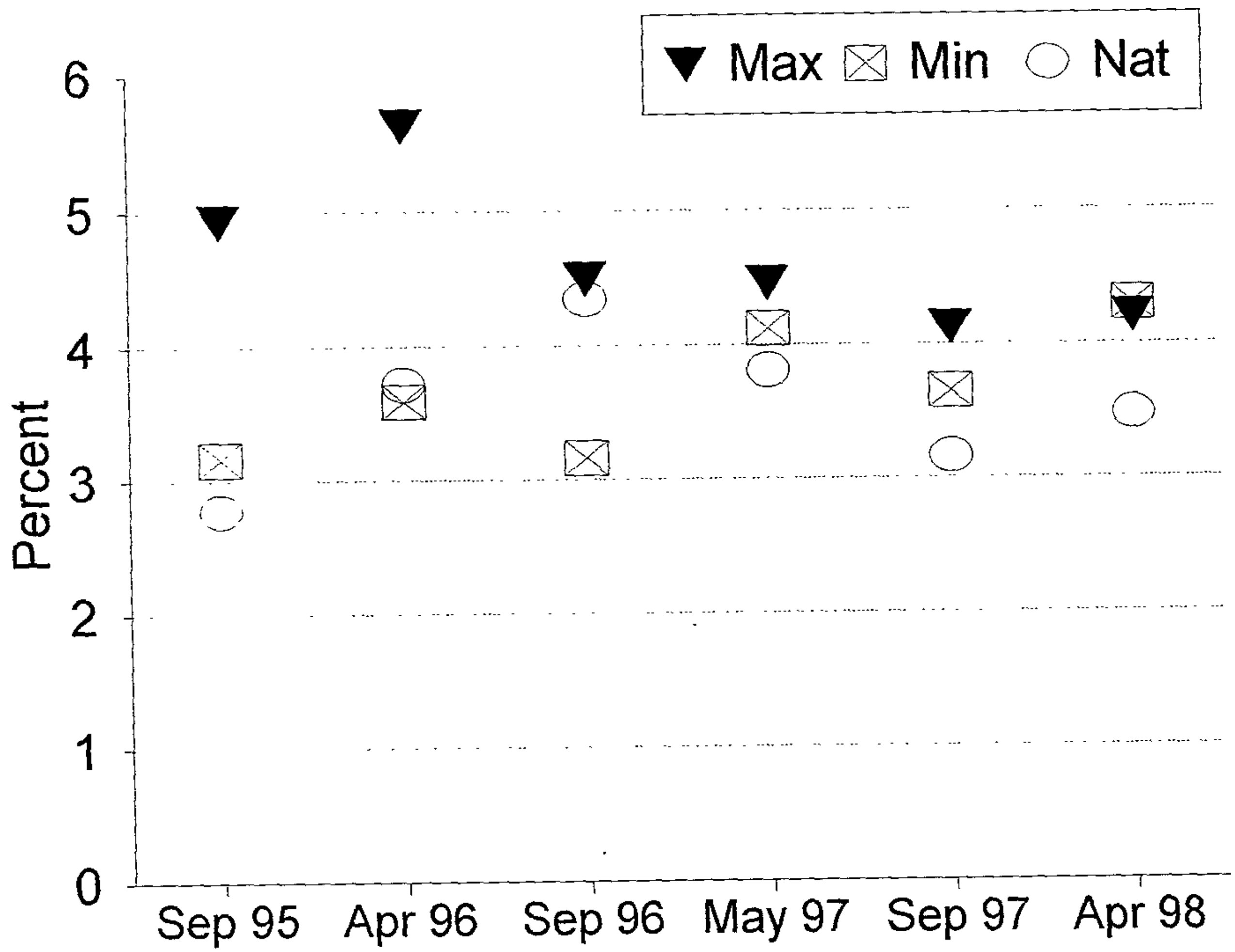


Figure 2. Mean surface (0-5 cm) sediment organic content (%) by habitat over time. N = 28-30 per habitat per month. Max = Maximum Impact, Min = Minimum Impact, Nat = Natural seagrass.

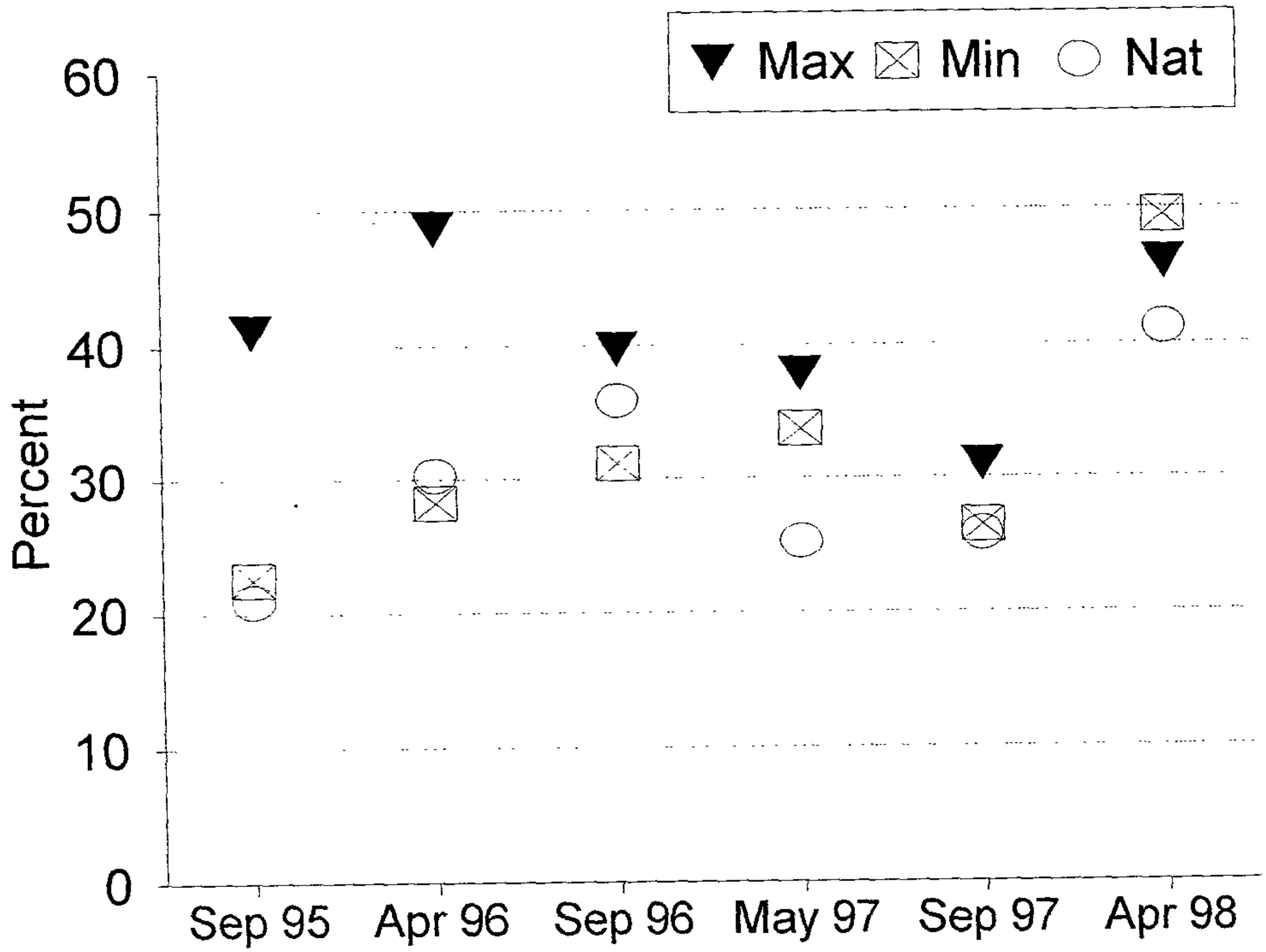


Figure 3. Mean surface (0-5 cm) sediment silt+clay content (%) by habitat over time. N = 28-30 per habitat per month. Max = Maximum Impact, Min = Minimum Impact, Nat = Natural Seagrass.

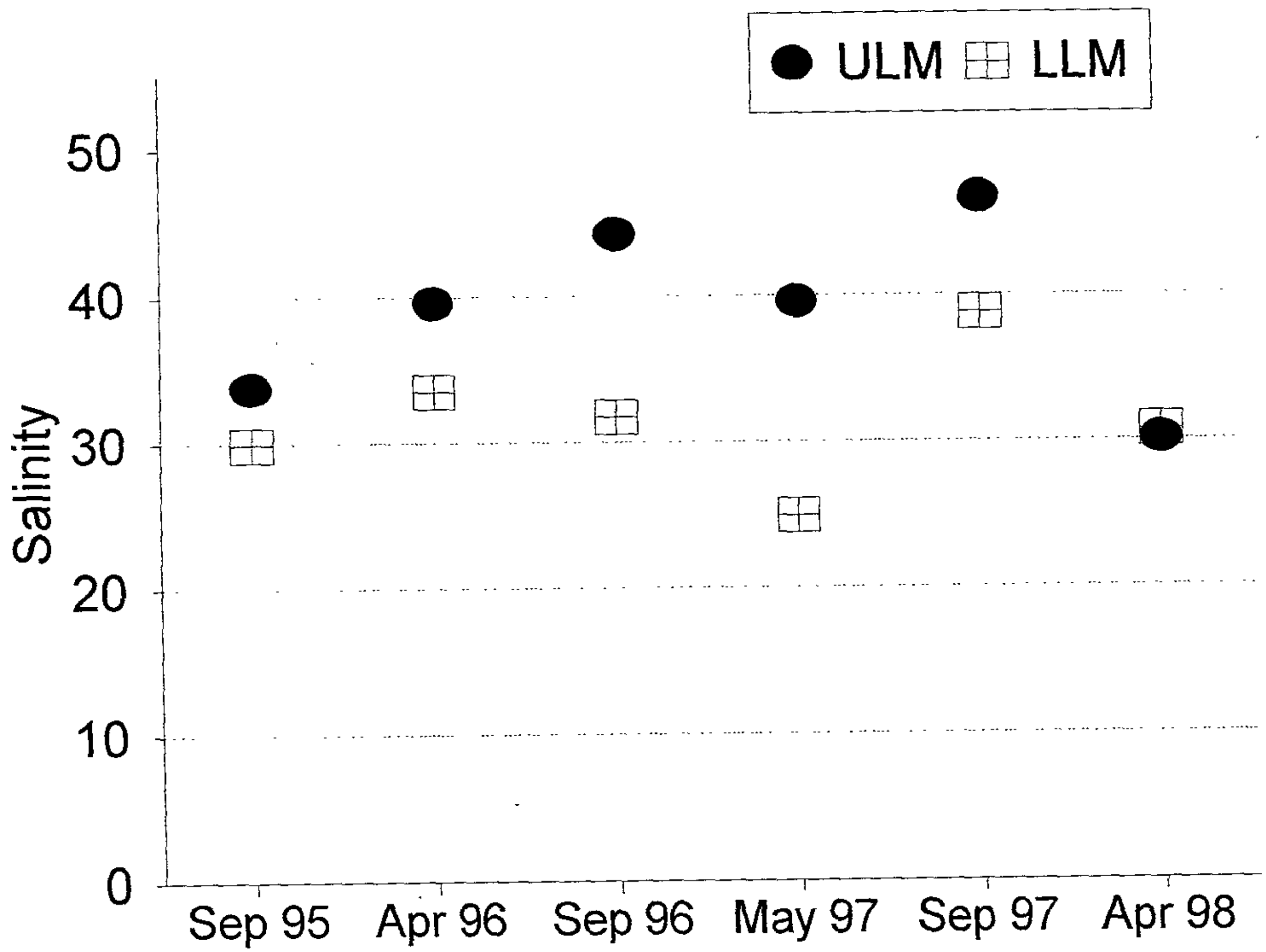


Figure 4. Mean salinity at Upper Laguna Madre (ULM) sites and Lower Laguna Madre (LLM) sites over time. N = 44-45 per locale per month.

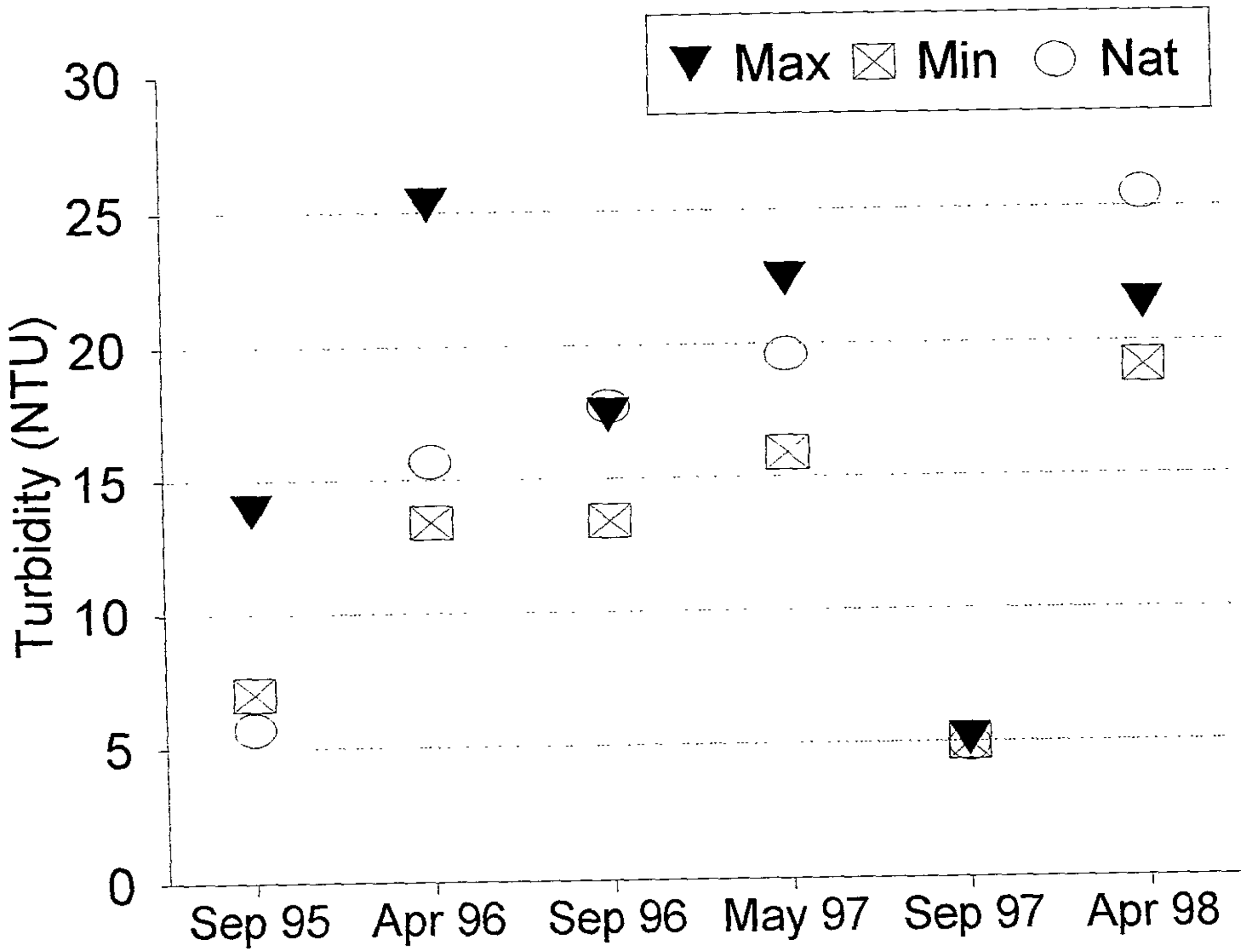


Figure 5. Mean water column turbidity by habitat over time. N = 30 per habitat per month, except n = 15 in April 1996 and only includes Upper Laguna Madre sites.

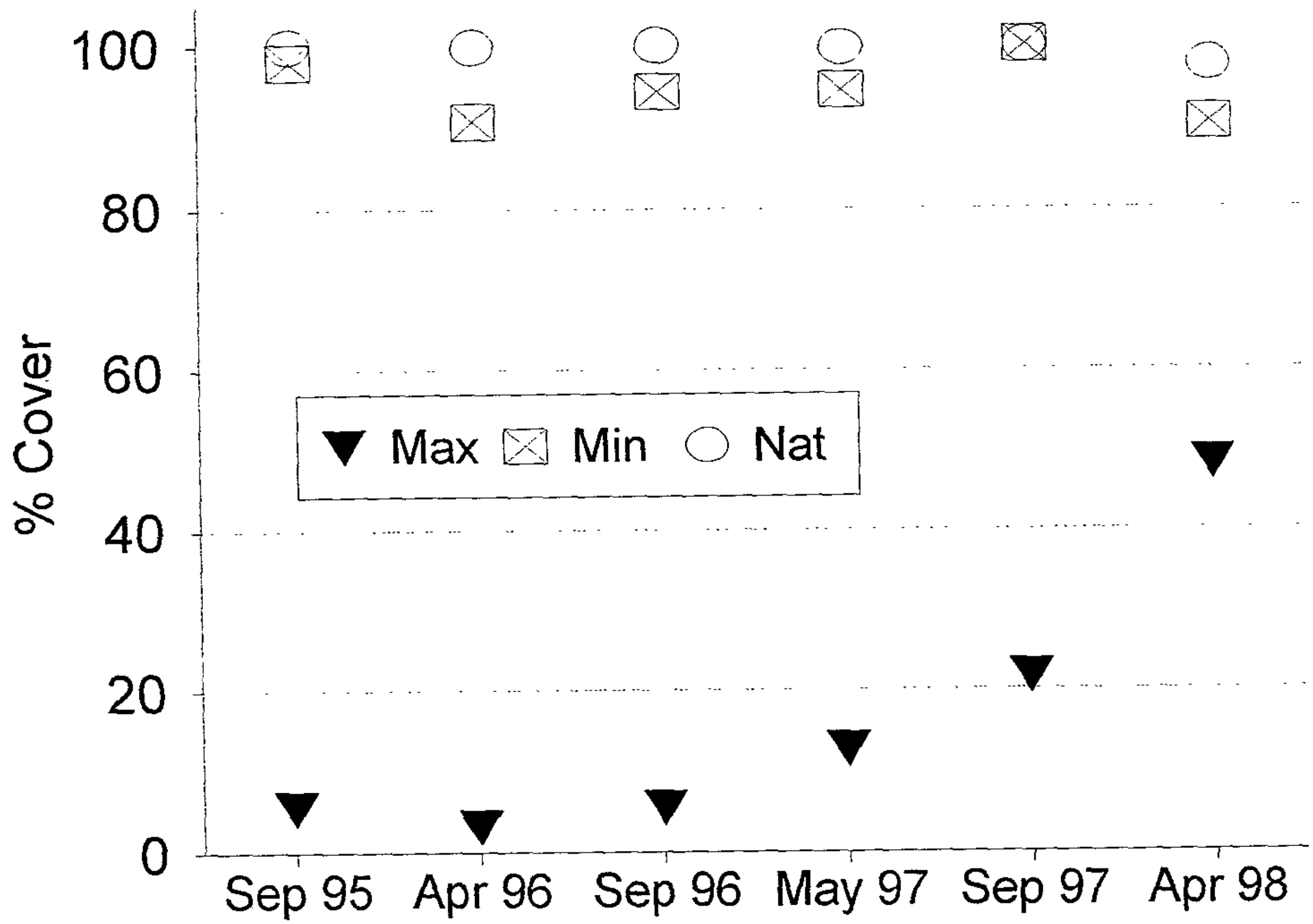


Figure 6. Mean seagrass coverage by habitat over time. N = 30 per habitat per month. Max = Maximum Impact, Min = Minimum Impact, Nat = Natural Seagrass.

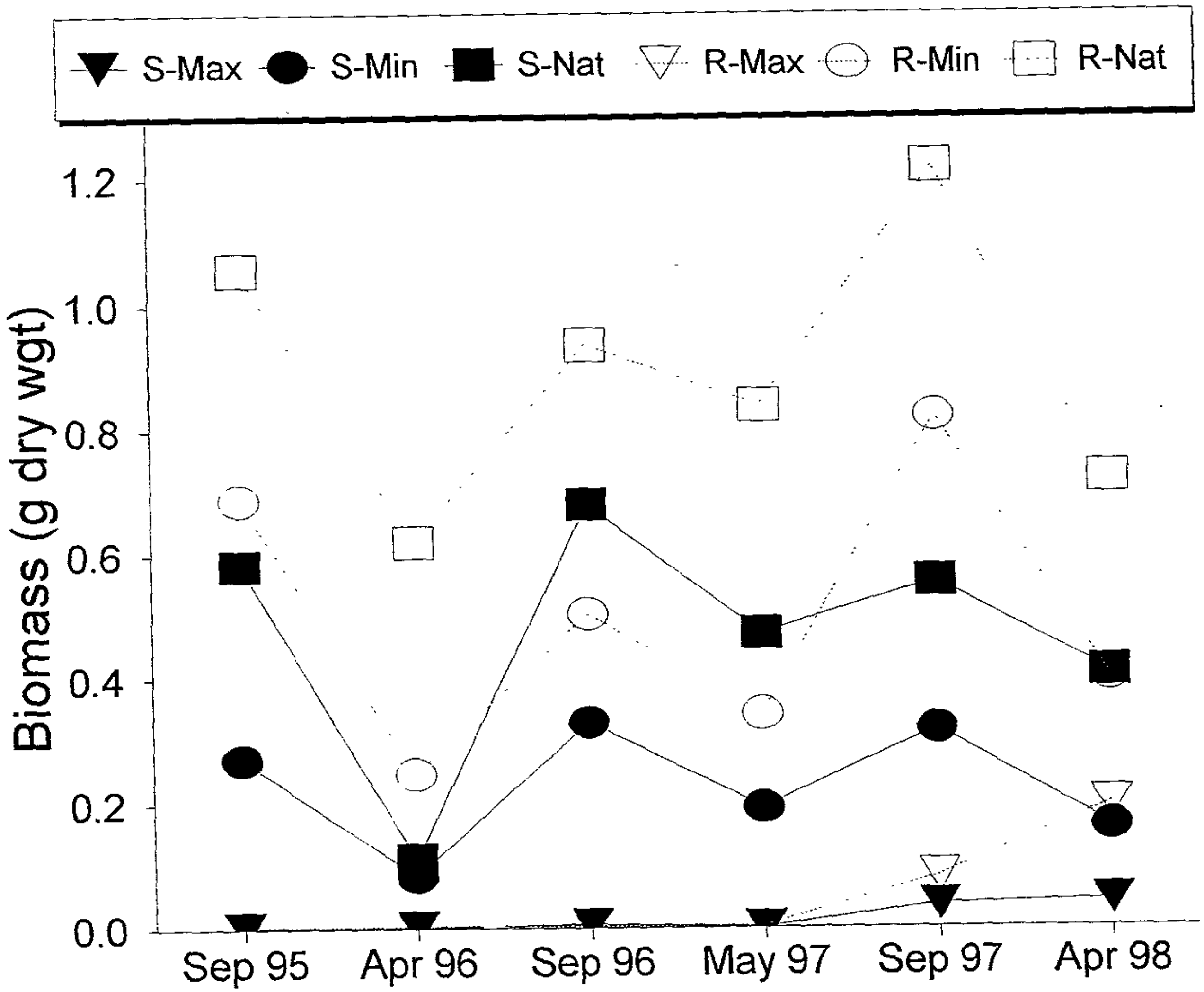


Figure 7. Mean seagrass shoot and root+rhizome biomass per 58.9 sq. cm by habitat over time. N = 20-30 per habitat per month. S = shoot, R = root, Max = Maximum Impact, Min = Minimum Impact, Nat = Natural Seagrass.

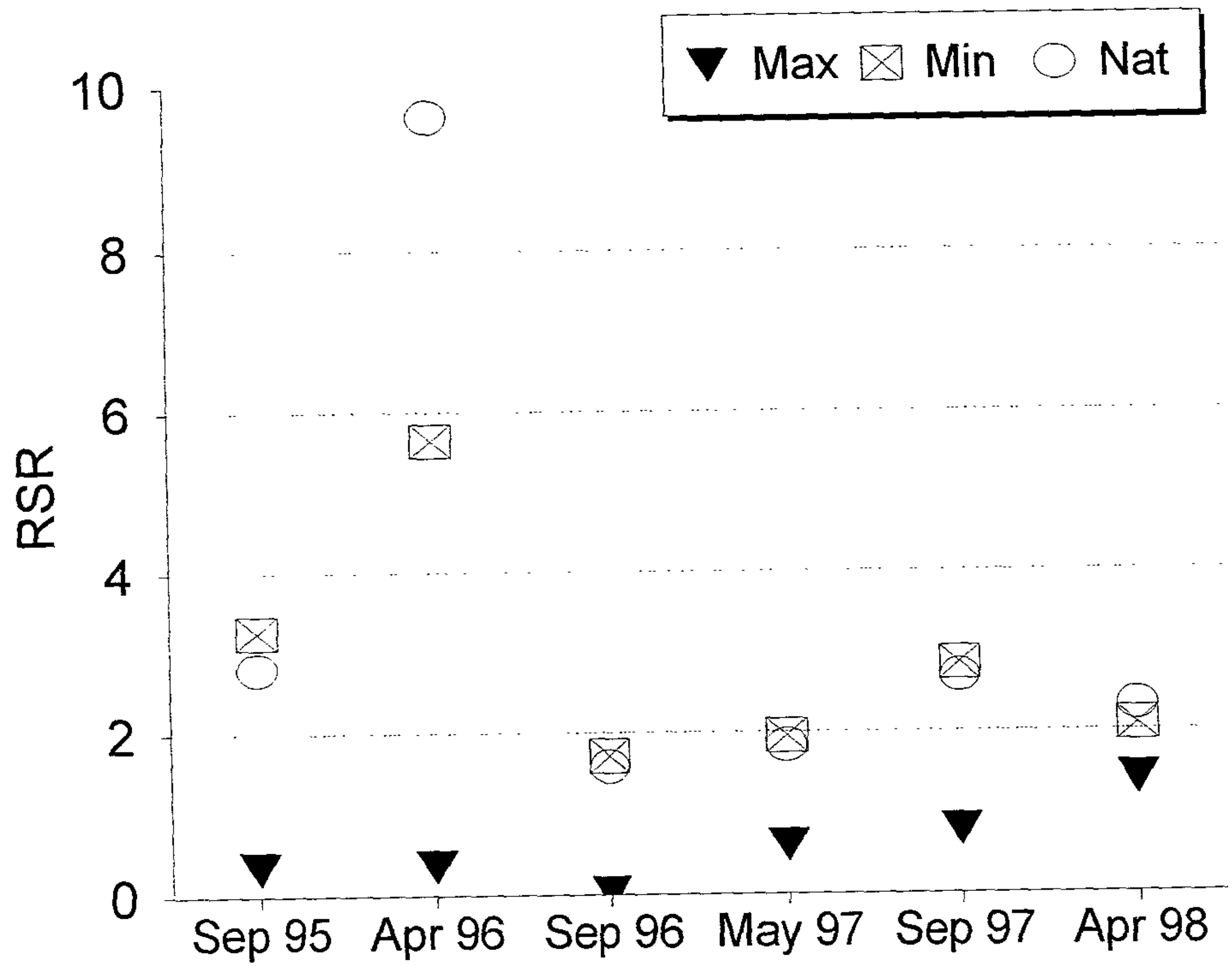


Figure 8. Mean seagrass root : shoot ratio (RSR) by habitat over time. N = 20-30 per habitat per month. Max = Maximum Impact, Min = Minimum Impact, Nat = Natural Seagrass.

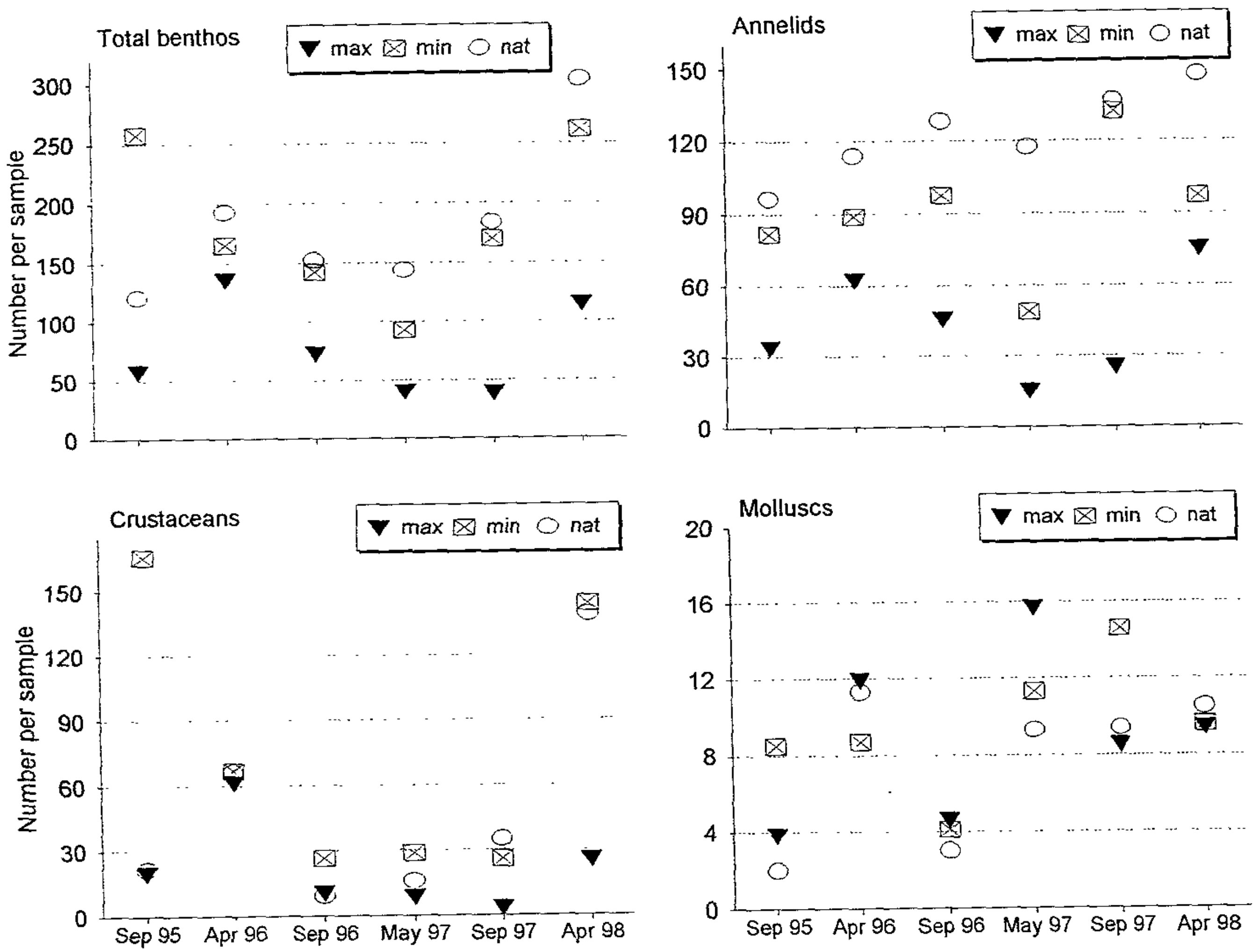


Figure 9. Mean densities of total benthos and major taxonomic groups by habitat over time. Sample = 3 pooled cores, each 5 cm diameter and 10 cm deep. N = 28-30 per habitat per month. Max = Maximum Impact, Min = Minimum Impact, Nat = Natural Seagrass.

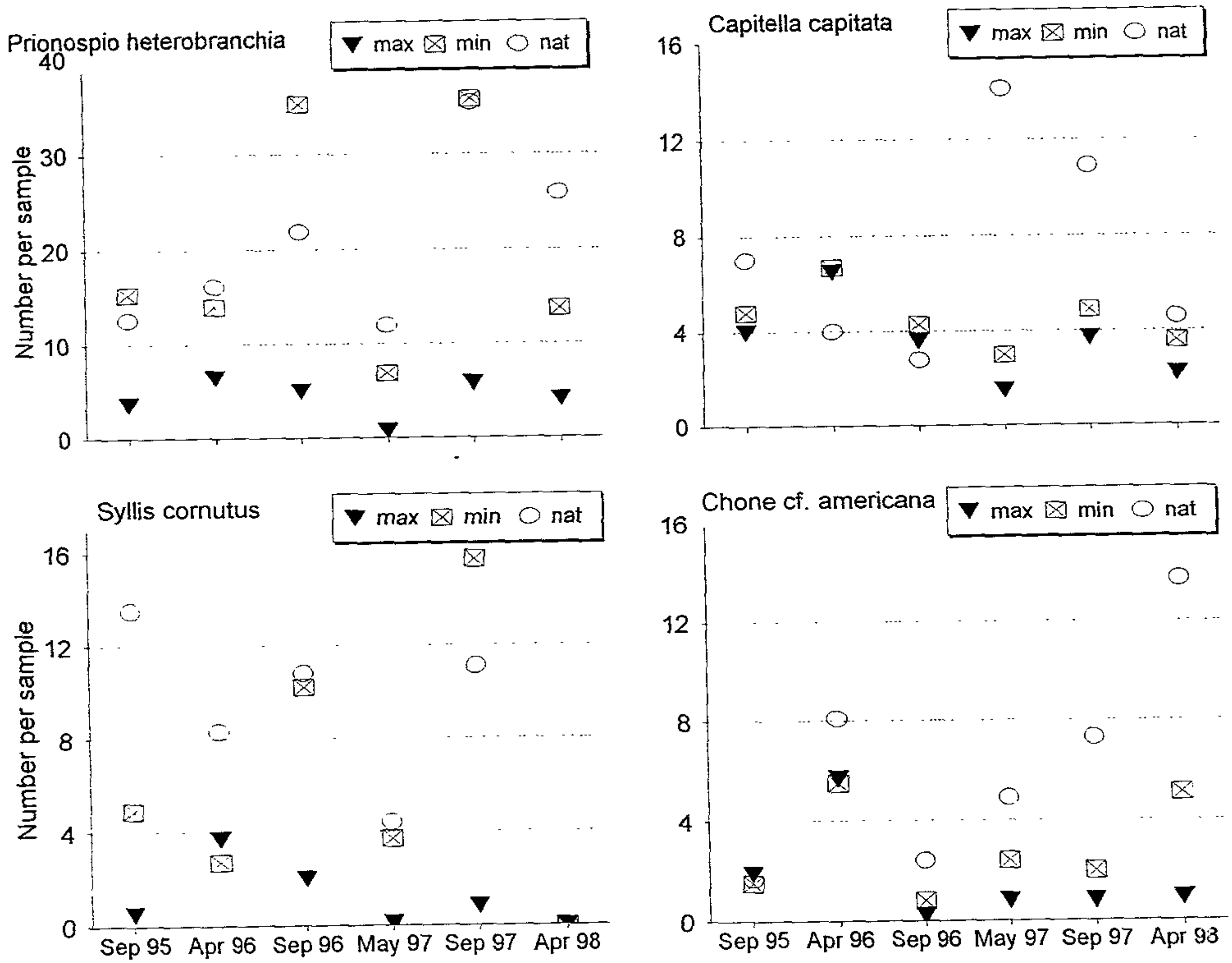


Figure 10. Mean densities of dominant annelids by habitat over time. Sample = 3 pooled cores, each 5 cm diameter and 10 cm deep. N = 28-30 per habitat per month. Max = Maximum Impact, Min = Minimum Impact, Nat = Natural Seagrass.

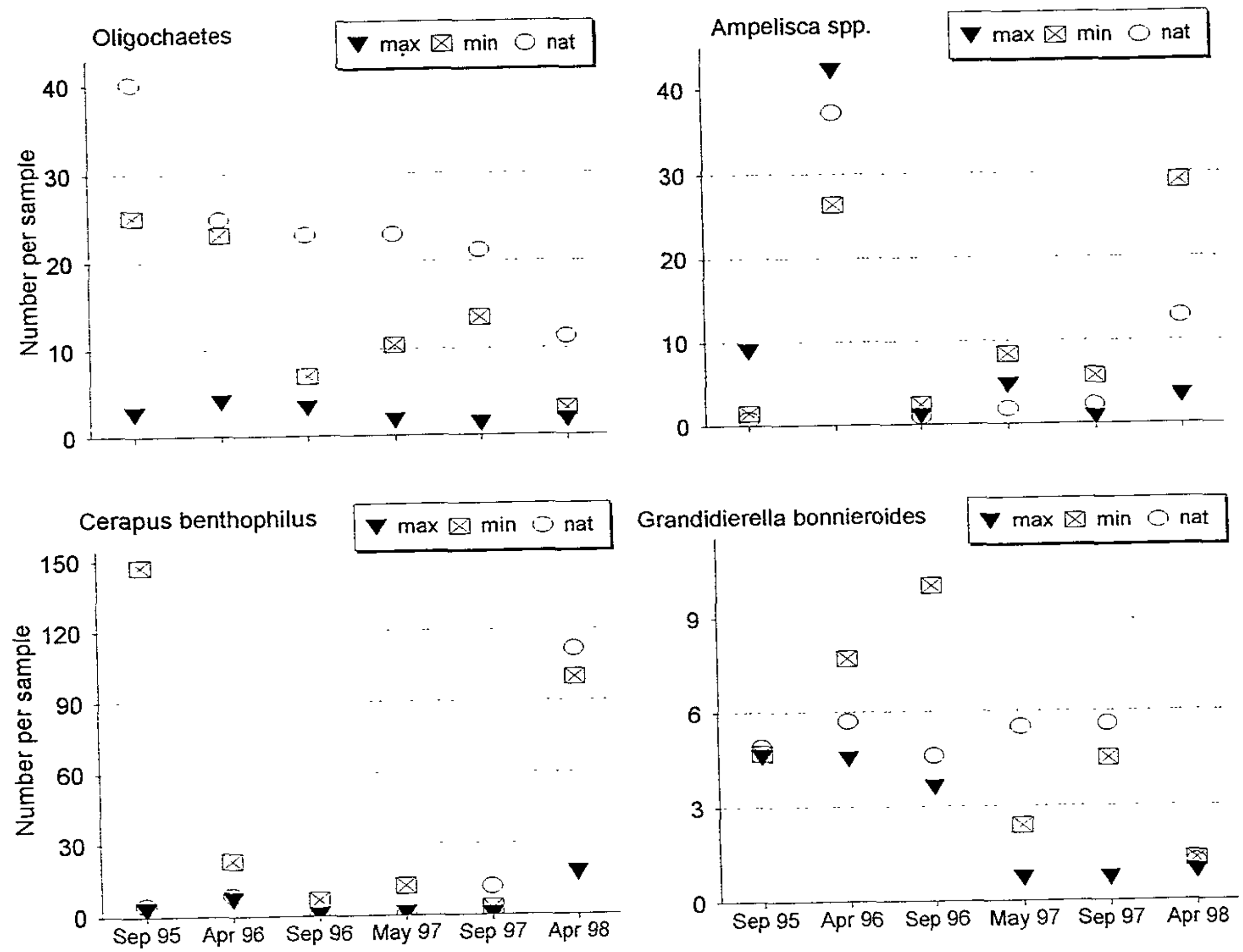


Figure 11. Mean densities of oligochaetes and dominant amphipods by habitat over time. Sample = 3 pooled cores, each 5 cm diameter and 10 cm deep. N = 28-30 per habitat per month. Max = Maximum Impact, Min = Minimum Impact, Nat = Natural Seagrass.

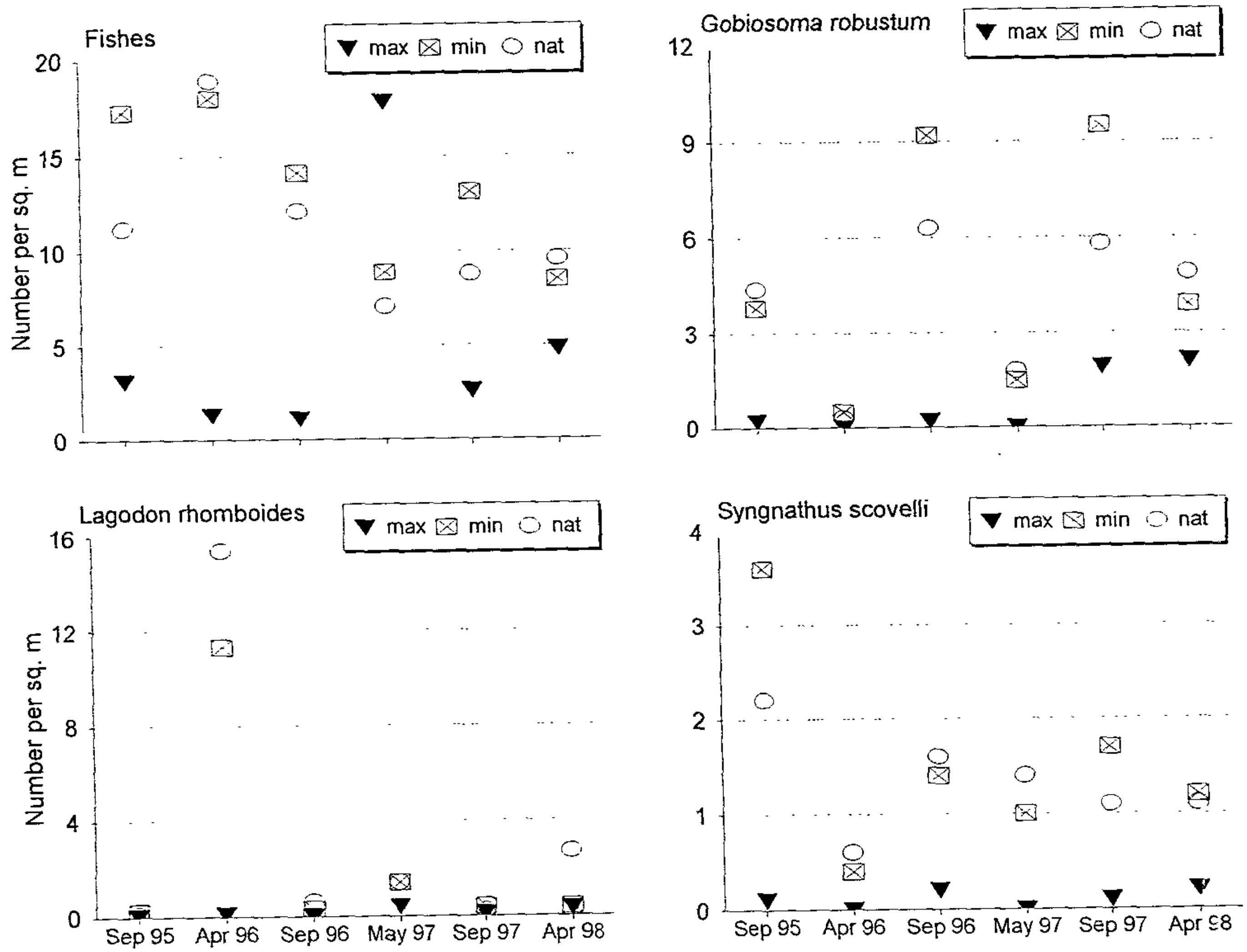


Figure 12. Mean densities of total fishes and dominant species by habitat over time. N = 30 per habitat per month. Max = Maximum Impact, Min = Minimum Impact, Nat = Natural Seagrass.

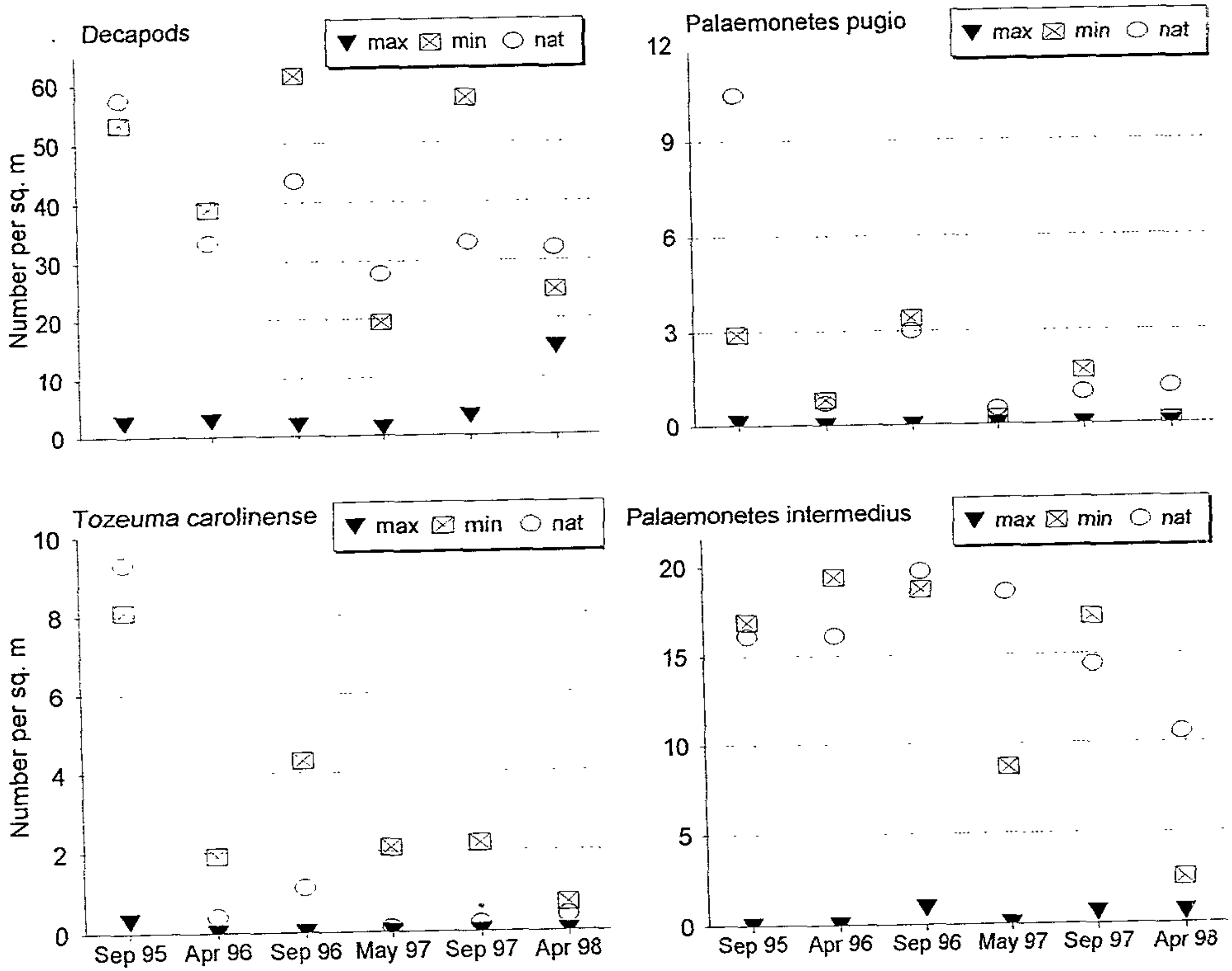


Figure 13. Mean densities of total decapods, and three dominant species not responding to increased seagrass cover, by habitat over time. N = 30 per habitat per month. Max = Maximum Impact, Min = Minimum Impact, Nat = Natural Seagrass.

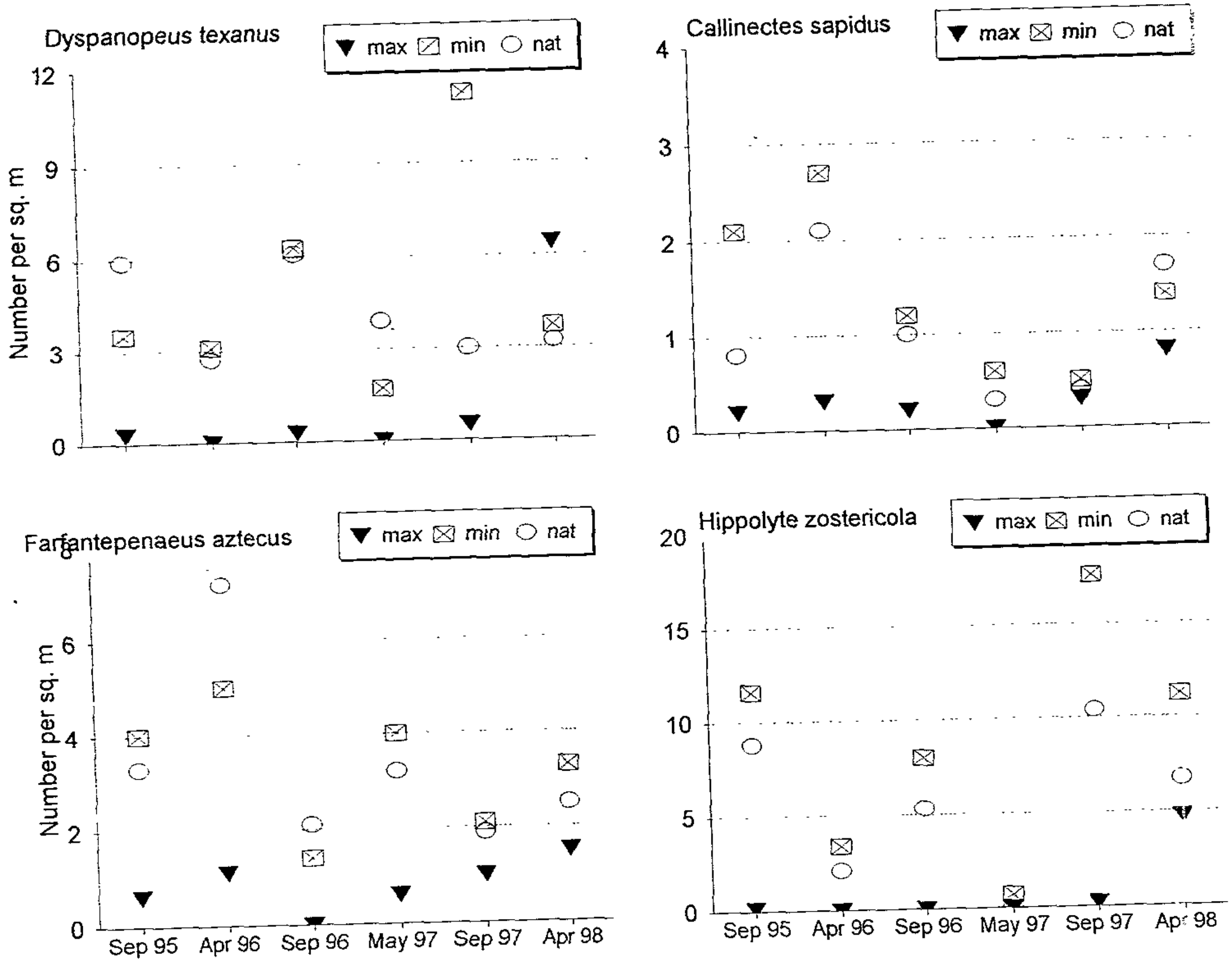


Figure 14. Mean densities of four dominant decapods apparently responding to increased seagrass cover, by habitat over time. N = 30 per habitat per month. Max = Maximum Impact, Min = Minimum Impact, Nat = Natural Seagrass.

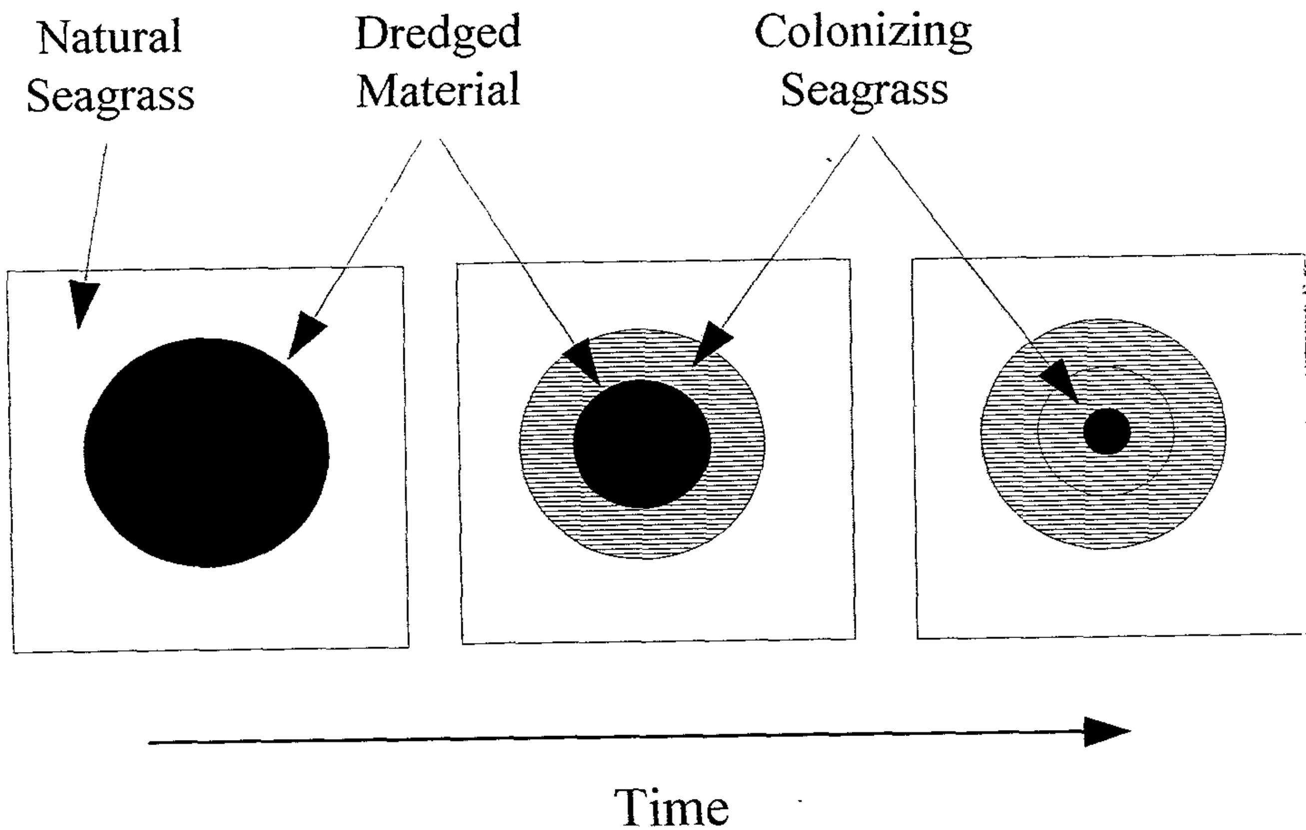


Figure 15. Diagrammatic representation of seagrass colonization of a dredged material deposit.

Appendix 1.

Sediment characteristics (as proportions) by locale and depth below sediment surface, pooled over sites within each locale (3) and habitats within sites (3). ULM = Upper Laguna Madre, LLM = Lower Laguna Madre. Particle sizes: rubble > 2.0 mm; sand 0.0625 - 2.0 mm; silt 0.0040 - 0.0625 mm; clay < 0.0040 mm.

			Organic content		Rubble		Sand		Silt		Clay	
Locale	Date		0-5 cm	5-10 cm	0-5 cm	5-10 cm	0-5 cm	5-10 cm	0-5 cm	5-10 cm	0-5 cm	5-10 cm
ULM	Sep 95	mean	0.0405	0.0514	0.0562	0.0538	0.6498	0.6241	0.0388	0.0466	0.2551	0.2756
		se	0.0040	0.0043	0.0131	0.0107	0.0371	0.0378	0.0050	0.0059	0.0342	0.0343
		n	44	45	43	44	43	44	43	44	43	44
	Apr 96	mean	0.0423	0.0492	0.0243	0.0283	0.6172	0.6140	0.0417	0.0404	0.3167	0.3174
		se	0.0042	0.0038	0.0042	0.0040	0.0363	0.0292	0.0049	0.0043	0.0337	0.0273
		n	45	45	45	45	45	45	45	45	45	45
	Sep 96	mean	0.0382	0.0509	0.0397	0.0336	0.6027	0.6169	0.0517	0.0437	0.3058	0.3057
		se	0.0034	0.0057	0.0060	0.0050	0.0324	0.0332	0.0163	0.0051	0.0308	0.0293
		n	45	45	45	45	45	45	45	45	45	45
	May 97	mean	0.0417	0.0434	0.0384	0.0439	0.6555	0.6732	0.0387	0.0485	0.2691	0.2344
		se	0.0044	0.0036	0.0062	0.0084	0.0358	0.0244	0.0047	0.0149	0.0347	0.0236
		n	45	45	45	45	45	45	45	45	45	45
	Sep 97	mean	0.0349	0.0334	0.0358	0.0339	0.7057	0.7335	0.0377	0.0446	0.2216	0.1887
		se	0.0033	0.0032	0.0066	0.0058	0.0290	0.0192	0.0042	0.0078	0.0274	0.0188
		n	45	45	44	44	45	45	45	45	45	45
	Apr 98	mean	0.0391	0.0359	0.0239	0.0341	0.5603	0.6227	0.0430	0.0425	0.3728	0.3006
		se	0.0039	0.0038	0.0054	0.0056	0.0368	0.0265	0.0136	0.0180	0.0333	0.0236
		n	45	45	44	45	44	45	44	45	44	45

Appendix 1 (continued)

LLM	Sep 95	mean	0.0314	0.0413	0.0627	0.0576	0.6744	0.6294	0.0938	0.1053	0.1719	0.2077
		se	0.0021	0.0031	0.0133	0.0115	0.0210	0.0225	0.0144	0.0154	0.0112	0.0161
		n	42	43	42	43	44	43	44	43	44	43
	Apr 96	mean	0.0440	0.0456	0.0370	0.0345	0.5915	0.6110	0.1084	0.1033	0.2632	0.2512
		se	0.0025	0.0026	0.0064	0.0049	0.0156	0.0157	0.0099	0.0100	0.0017	0.0101
		n	45	45	45	45	45	45	45	45	45	45
	Sep 96	mean	0.0418	0.0438	0.0388	0.0453	0.6082	0.6130	0.1132	0.0854	0.2406	0.2564
		se	0.0027	0.0030	0.0089	0.0083	0.0262	0.0238	0.0221	0.0103	0.0183	0.0159
		n	45	45	44	45	45	45	45	45	45	45
	May 97	mean	0.0409	0.3620	0.0488	0.0462	0.6162	0.6786	0.1219	0.1056	0.2153	0.1706
		se	0.0033	0.0026	0.0105	0.0112	0.0292	0.0206	0.0219	0.0148	0.0178	0.0118
		n	45	45	43	44	45	45	45	45	45	45
	Sep 97	mean	0.0379	0.0407	0.0485	0.0412	0.6578	0.6911	0.0817	0.0870	0.2131	0.1807
		se	0.0034	0.0028	0.0104	0.0061	0.0264	0.0218	0.0110	0.0117	0.0218	0.0114
		n	45	45	44	45	45	45	45	45	45	45
	Apr 98	mean	0.0408	0.0449	0.0303	0.0409	0.4770	0.5336	0.1277	0.0911	0.3650	0.3345
		se	0.0033	0.0031	0.0061	0.0070	0.0279	0.0207	0.0193	0.0125	0.0226	0.0167
		n	45	45	45	45	45	45	45	45	45	45

Appendix 2.

Sediment characteristics (as proportions) by habitat and depth below sediment surface, pooled over locales (2) and sites within locales.

Max = Maximum Impact, Min = Minimum Impact, Nat = Natural Seagrass. Particle sizes: rubble > 2.0 mm; sand 0.0625 - 2.0 mm;

silt 0.0040 - 0.0625 mm; clay < 0.0040 mm.

			Organic content		Rubble		Sand		Silt		Clay	
Habitat	Date		0-5 cm	5-10 cm	0-5 cm	5-10 cm	0-5 cm	5-10 cm	0-5 cm	5-10 cm	0-5 cm	5-10 cm
Max	Sep 95	mean	0.0493	0.0522	0.0502	0.0422	0.5421	0.5392	0.0805	0.0921	0.3308	0.3265
		se	0.0054	0.0057	0.0171	0.0143	0.0473	0.0490	0.0140	0.0195	0.0463	0.0471
		n	28	29	26	30	28	30	28	30	28	30
	Apr 96	mean	0.0563	0.0554	0.0213	0.0214	0.4921	0.5436	0.0863	0.0712	0.4003	0.3638
		se	0.0051	0.0047	0.0051	0.0041	0.0440	0.0379	0.0092	0.0075	0.0431	0.0364
		n	30	30	30	30	30	30	30	30	30	30
	Sep 96	mean	0.0450	0.0404	0.0277	0.0212	0.5759	0.6031	0.0884	0.0676	0.3089	0.3081
		se	0.0048	0.0051	0.0051	0.0037	0.0452	0.0441	0.0320	0.0114	0.0421	0.0388
		n	30	30	29	30	30	30	30	30	30	30
	May 97	mean	0.0446	0.0363	0.0337	0.0348	0.5913	0.6726	0.0749	0.0713	0.3035	0.2225
		se	0.0062	0.0044	0.0088	0.0109	0.0496	0.0360	0.0130	0.0231	0.0482	0.0345
		n	30	30	27	29	30	30	30	30	30	30
	Sep 97	mean	0.0412	0.0387	0.0260	0.0344	0.6647	0.7082	0.0623	0.0517	0.2470	0.2069
		se	0.0053	0.0042	0.0047	0.0065	0.0388	0.0291	0.0088	0.0081	0.0365	0.0268
		n	30	30	30	29	30	30	30	30	30	30
	Apr 98	mean	0.0420	0.0375	0.0318	0.0383	0.5088	0.6161	0.0797	0.0521	0.3797	0.2935
		se	0.0052	0.0046	0.0088	0.0081	0.0453	0.0316	0.0243	0.0162	0.0420	0.0284
		n	30	30	30	30	30	30	30	30	30	30

Appendix 2 (continued)

Min	Sep 95	mean	0.0316	0.0449	0.0751	0.0609	0.6994	0.6425	0.0637	0.0742	0.1618	0.2223
		se	0.0027	0.0047	0.0182	0.0129	0.0264	0.0315	0.0177	0.0115	0.0142	0.0234
		n	29	29	29	28	29	28	29	28	29	28
	Apr 96	mean	0.0359	0.0379	0.0267	0.0293	0.6674	0.6851	0.0637	0.0671	0.2422	0.2185
		se	0.0022	0.0026	0.0050	0.0040	0.0173	0.0156	0.0113	0.0106	0.0116	0.0098
		n	30	30	30	30	30	30	30	30	30	30
	Sep 96	mean	0.0316	0.0383	0.0343	0.0333	0.6542	0.6857	0.0581	0.0505	0.2533	0.2305
		se	0.0027	0.0039	0.0076	0.0063	0.0297	0.0212	0.0089	0.0090	0.0252	0.0157
		n	30	30	30	30	30	30	30	30	30	30
	May 97	mean	0.0412	0.0363	0.0430	0.0425	0.6202	0.7139	0.1008	0.0627	0.2361	0.1809
		se	0.0042	0.0038	0.0104	0.0099	0.0380	0.0203	0.0313	0.0091	0.0247	0.0160
		n	30	30	30	30	30	30	30	30	30	30
	Sep 97	mean	0.0365	0.0326	0.0415	0.0300	0.6972	0.7487	0.0470	0.0582	0.2171	0.1631
		se	0.0042	0.0030	0.0086	0.0054	0.0368	0.0219	0.0092	0.0108	0.0331	0.0124
		n	30	30	28	30	30	30	30	30	30	30
	Apr 98	mean	0.0430	0.0347	0.0148	0.0305	0.4909	0.5865	0.0988	0.0823	0.3955	0.3007
		se	0.0050	0.0037	0.0038	0.0074	0.0452	0.0329	0.0225	0.0277	0.0356	0.0243
		n	30	30	29	30	29	30	29	30	29	30

Appendix 2 (continued)

Nat	Sep 95	mean	0.0277	0.0424	0.0521	0.0644	0.7386	0.7020	0.0565	0.0598	0.1527	0.1738
		se	0.0022	0.0035	0.0129	0.0133	0.0231	0.0216	0.0101	0.0122	0.0125	0.0109
		n	29	30	30	29	30	29	30	29	30	29
	Apr 96	mean	0.0372	0.0490	0.0440	0.0434	0.6535	0.6087	0.0752	0.0773	0.2273	0.2705
		se	0.0039	0.0038	0.0088	0.0071	0.0260	0.0218	0.0131	0.0141	0.0184	0.0154
		n	30	30	30	30	30	30	30	30	30	30
	Sep 96	mean	0.0435	0.0633	0.0554	0.0639	0.5864	0.5560	0.1009	0.0755	0.2574	0.3046
		se	0.0029	0.0064	0.0127	0.0115	0.0300	0.0332	0.0261	0.0111	0.0235	0.0268
		n	30	30	30	30	30	30	30	30	30	30
	May 97	mean	0.0381	0.0467	0.0535	0.0576	0.6961	0.6412	0.0652	0.0972	0.1870	0.2041
		se	0.0036	0.0031	0.0120	0.0147	0.0281	0.0229	0.0123	0.0212	0.0189	0.0145
		n	30	30	29	30	30	30	30	30	30	30
	Sep 97	mean	0.0316	0.0398	0.0590	0.0482	0.6834	0.6801	0.0697	0.0875	0.1879	0.1841
		se	0.0021	0.0038	0.0152	0.0092	0.0260	0.0235	0.0140	0.0169	0.0173	0.0140
		n	30	30	30	30	30	30	30	30	30	30
	Apr 98	mean	0.0348	0.0491	0.0344	0.0436	0.5539	0.5319	0.0795	0.0660	0.3323	0.3585
		se	0.0025	0.0043	0.0072	0.0078	0.0294	0.0238	0.0192	0.0104	0.0234	0.0211
		n	30	30	30	30	30	30	30	30	30	30

Appendix 3.

Similarity of surface (0-5 cm) and subsurface (5-10 cm) sediment characteristics by habitat and date, determined by regression.

Max = Maximum Impact, Min = Minimum Impact, Nat = Natural Seagrass. N = 26-30 pairs per month.

		Organic content			Sand			Silt			Clay		
Habitat	Date	Adj. R2	F	P	Adj. R2	F	P	Adj. R2	F	P	Adj. R2	F	P
Max	Sep 95	0.482	26.13	<0.001	0.390	18.24	<0.001	0.498	27.73	<0.001	0.387	17.94	<0.001
	Apr 96	0.433	23.16	<0.001	0.746	85.99	<0.001	0.352	16.77	<0.001	0.773	99.72	<0.001
	Sep 96	0.128	5.27	0.029	0.145	0.59	0.022	0.003	0.09	0.770	0.371	18.09	<0.001
	May 97	0.378	18.65	<0.001	0.121	4.98	0.033	0.101	4.25	0.048	0.361	17.37	<0.001
	Sep 97	0.611	46.64	<0.001	0.248	10.57	0.003	0.543	35.48	<0.001	0.275	12.00	0.002
	Apr 98	0.531	33.84	<0.001	0.600	44.47	<0.001	0.267	11.58	0.002	0.460	25.68	<0.001
Min	Sep 95	0.055	2.64	0.116	0.227	8.94	0.006	0.110	4.35	0.047	0.281	11.56	0.002
	Apr 96	0.001	0.97	0.334	0.304	13.69	<0.001	0.701	68.99	<0.001	0.014	0.38	0.541
	Sep 96	0.018	0.52	0.476	0.436	23.39	<0.001	0.545	35.74	<0.001	0.359	17.25	<0.001

Appendix 3 (continued)

	May 97	0.004	0.11	0.741	0.013	0.37	0.547	0.284	12.51	0.001	0.018	1.53	0.227
	Sep 97	0.101	4.24	0.049	0.433	23.14	<0.001	0.428	22.72	<0.001	0.484	28.18	<0.001
	Apr 98	0.265	11.48	0.002	0.493	28.26	<0.001	0.088	3.72	0.064	0 108	4.40	0.045
Nat	Sep 95	0.332	14.93	<0.001	0.615	45.74	<0.001	0.505	29.54	<0.001	0.104	4.24	0.049
	Apr 96	0.119	0.49	0.035	0.277	12.12	0.002	0.056	2.71	0.111	0.086	3.74	0.063
	Sep 96	0.057	2.77	0.107	0.003	1.77	0.194	0.184	7.52	0.011	0.032	0.92	0.345
	May 97	0.018	0.50	0.485	0.306	13.80	0.001	0.429	22.75	<0.001	0.096	4.08	0.053
	Sep 97	0.152	6.21	0.019	0.303	13.62	0.001	0.338	15.81	<0.001	0.014	0.39	0.538
	Apr 98	0.004	0.11	0.743	0.104	4.36	0.046	0.204	8.45	0.007	0.124	5.10	0.032

Appendix 4.

Water column characteristics by locale and date, pooled over sites within each locale (3) and habitats within sites (3).

ULM = Upper Laguna Madre, LLM = Lower Laguna Madre. Dash (-) = no turbidity data available.

		Temperature (C)		Salinity		Depth (cm)		Turbidity (NTU)	
Date		ULM	LLM	ULM	LLM	ULM	LLM	ULM	LLM
Sep 95	mean	30.2	30.2	33.8	29.9	58.4	48.5	7.7	10.0
	se	0.1	0.2	0.5	0.6	2.4	1.4	0.8	1.9
	n	45	45	45	45	45	45	45	45
Apr 96	mean	22.7	21.6	39.6	33.5	52.6	43.2	18.1	-
	se	0.2	0.1	0.3	0.5	2.5	2.3	1.6	-
	n	45	45	45	45	44	45	45	-
Sep 96	mean	31.8	31.0	44.2	31.7	57.8	45.6	15.2	17.1
	se	0.1	0.1	0.4	0.3	1.7	2.2	1.8	2.4
	n	45	45	45	45	45	45	45	45
May 97	mean	27.2	25.3	39.6	24.9	64.6	54.7	15.2	23.4
	se	0.1	0.3	0.4	0.8	1.4	1.6	2.1	1.8
	n	45	45	45	44	45	45	44	45
Sep 97	mean	30.9	30.3	46.6	38.8	70.5	53.9	5.8	4.3
	se	0.2	0.2	0.4	0.9	2.4	2.3	0.6	0.3
	n	45	45	45	44	45	45	45	45
Apr 98	mean	24.6	22.4	30.1	30.7	77.0	64.9	23.6	20.4
	se	0.1	0.2	0.2	0.5	2.7	3.6	1.4	1.7
	n	45	45	45	45	45	45	45	45

Appendix 5.

Water column characteristics by habitat and date, pooled over locale (2) and sites within locales (3). Max = Maximum Impact, Min = Minimum Impact, Nat = Natural Seagrass.

Date		Temperature (C)			Salinity			Depth (cm)			Turbidity (NTU)		
		Max	Min	Nat	Max	Min	Nat	Max	Min	Nat	Max	Min	Nat
Sep 95	mean	29.8	30.2	30.5	31.7	31.8	32.0	46.1	58.5	55.8	13.9	7.0	5.7
	se	0.2	0.2	0.2	0.8	0.8	0.8	2.2	2.9	2.0	2.7	1.1	0.4
	n	30	30	30	30	30	30	30	30	30	30	30	30
Apr 96	mean	22.4	21.9	22.0	36.1	36.6	36.8	40.9	50.9	51.9	25.3	13.4	15.7
	se	0.3	0.3	0.2	0.7	0.9	0.8	3.3	2.5	3.0	3.5	1.9	1.9
	n	30	30	30	30	30	30	30	30	29	15	15	15
Sep 96	mean	31.5	30.8	31.8	37.8	38.0	38.2	48.4	48.6	58.1	17.4	13.4	17.7
	se	0.2	0.2	0.2	1.1	1.1	1.4	2.9	2.7	1.8	2.3	2.2	3.2
	n	30	30	30	30	30	30	30	30	30	30	30	30
May 97	mean	25.6	26.1	27.1	32.5	33.9	30.6	58.7	56.2	64.1	22.4	15.9	19.6
	se	0.3	0.3	0.3	1.5	1.5	1.7	2.5	2.0	1.2	3.1	1.6	2.5
	n	30	30	30	30	29	30	30	30	30	30	29	30
Sep 97	mean	29.9	30.5	31.4	43.7	42.2	42.3	61.2	57.9	67.6	5.1	5.0	4.9
	se	0.2	0.3	0.2	0.7	1.4	1.1	4.1	2.5	2.7	0.7	0.5	0.5
	n	30	30	30	29	30	30	30	30	30	30	30	30
Apr 98	mean	23.3	23.4	23.8	31.6	31.1	28.5	75.6	67.9	69.4	21.4	19.1	25.5
	se	0.3	0.3	0.3	0.3	0.4	0.4	5.4	3.1	3.2	2.0	1.2	2.3
	n	30	30	30	30	30	30	30	30	30	30	30	30

Appendix 6.

Seagrass characteristics by locale and date, pooled over sites within each locale (3) and habitats within sites (3). ULM = Upper Laguna Madre, LLM = Lower Laguna Madre. Biomass in g dry weight per 58.9 sq. cm. RSR = root : shoot ratio.

		Coverage (%)		Shoot biomass		Root biomass		RSR	
Date		ULM	LLM	ULM	LLM	ULM	LLM	ULM	LLM
Sep 95	mean	65.7	70.1	0.2709	0.2928	0.5072	0.6503	1.83	2.42
	se	7.0	0.6	0.0545	0.0592	0.0873	0.0948	0.28	0.42
	n	45	45	45	44	45	44	45	44
Apr 96	mean	67.1	62.1	0.0931	0.0391	0.3558	0.2251	2.74	7.68
	se	6.8	6.8	0.0170	0.0076	0.1149	0.0386	0.61	1.74
	n	45	45	45	45	45	45	45	45
Sep 96	mean	65.7	67.6	0.4325	0.2430	0.5996	0.3624	1.14	1.06
	se	6.7	6.8	0.0783	0.0493	0.0967	0.0660	0.21	0.16
	n	45	45	45	45	45	45	45	45
May 97	mean	67.5	70.5	0.3503	0.0937	0.6222	0.1673	1.26	1.66
	se	6.7	6.0	0.0810	0.0218	0.1265	0.0485	0.20	0.44
	n	45	45	45	45	45	45	45	45
Sep 97	mean	69.6	77.7	0.1563	0.3348	0.4918	0.7048	1.54	2.15
	se	6.7	5.6	0.0414	0.0525	0.1308	0.0916	0.40	0.20
	n	45	45	26	45	26	45	26	45
Apr 98	mean	78.6	78.9	0.1765	0.2331	0.5712	0.3082	2.53	1.33
	se	5.5	5.6	0.0377	0.0743	0.1246	0.0717	0.50	0.20
	n	45	45	45	45	45	45	45	45

Appendix 7.

Seagrass characteristics by habitat and date, pooled over locale (2) and sites within locales (3). Max = Maximum Impact, Min = Minimum Impact, Nat = Natural Seagrass. Biomass in g dry weight per 58.9 sq. cm. RSR = root : shoot ratio.

		Coverage (%)			Shoot biomass			Root biomass			RSR		
Date		Max	Min	Nat	Max	Min	Nat	Max	Min	Nat	Max	Min	Nat
Sep 95	mean	5.6	98.1	100.0	0.0017	0.2709	0.5827	0.0034	0.6880	1.0585	0.34	3.26	2.80
	se	1.9	1.7	0.0	0.0014	0.0329	0.0901	0.0027	0.0603	0.1238	0.32	0.36	0.44
	n	30	30	30	30	30	29	30	30	29	30	30	29
Apr 96	mean	3.2	90.8	99.9	0.0017	0.0846	0.1119	0.0029	0.2482	0.6202	0.36	5.64	9.63
	se	1.0	3.7	0.1	0.0013	0.0179	0.0176	0.0016	0.0447	0.1588	0.20	1.70	1.98
	n	30	30	30	30	30	30	30	30	30	30	30	30
Sep 96	mean	5.5	94.4	100.0	0.0056	0.3283	0.6790	0.0027	0.5034	0.9369	0.02	1.71	1.58
	se	2.4	2.3	0.0	0.0056	0.0603	0.0945	0.0027	0.0720	0.1112	0.02	0.28	0.16
	n	30	30	30	30	30	30	30	30	30	30	30	30
May 97	mean	12.7	94.5	99.7	0.0010	0.1927	0.4723	0.0036	0.3420	0.8387	0.60	1.95	1.83
	se	3.4	2.7	0.3	0.0008	0.0302	0.1137	0.0026	0.0713	0.1728	0.56	0.36	0.24
	n	30	30	30	30	30	30	30	30	30	30	30	30
Sep 97	mean	21.6	100.0	99.3	0.0372	0.3177	0.5552	0.0833	0.8216	1.2177	0.78	2.85	2.68
	se	5.7	0.0	0.7	0.0182	0.0373	0.0830	0.0370	0.1028	0.1227	0.23	0.31	0.32
	n	30	30	30	30	20	21	30	20	21	30	20	21
Apr 98	mean	48.1	90.5	97.6	0.0436	0.1625	0.4083	0.1978	0.4010	0.7202	1.40	2.08	2.32
	se	8.2	4.4	1.9	0.0152	0.0389	0.1084	0.0785	0.1452	0.1296	0.43	0.61	0.36
	n	30	30	30	30	30	30	30	30	30	30	30	30

Appendix 8

Benthic organisms collected during the study period, summed over all collections by habitat. N = 180, 178, and 177 for Maximum Impact, Minimum Impact, and Natural Seagrass, respectively. Species identified with letters (e.g., Autolytus sp. A) refer to designations by Uebelacker and Johnson (1984). Organisms not identified to species (i.e., to phylum, class, subclass, order, family, or genus) generally were juvenile or damaged specimens.

	Maximum Impact	Minimum Impact	Natural Seagrass	Total
Annelids	7692	16212	21798	45702
Ampharetidae	10	0	2	12
Aphelochaeta marioni	20	7	7	34
Arenicola cristata	5	9	10	24
Aricidea fragilis	1	0	1	2
Aricidea taylori	3	0	0	3
Armandia maculata	0	1	0	1
Autolytus sp. A	0	5	7	12
Axiothella cf. mucosa	3	4	10	17
Axiothella sp. A	38	31	7	76
Brania sp. A	0	1	1	2
Capitella capitata	646	812	1268	2726
Capitella jonesi	0	7	3	10
Capitella giardi	22	16	18	56
Capitella sp. (8 setae - Henderson)	1	5	23	29
Capitellidae	3	19	28	50
Ceratonereis irritabilis	31	166	11	208
Ceratonereis versipedata	11	30	35	76
Chone cf. americana	308	517	1120	1945
Clymenella torquata	0	0	4	4
Demonax microphthalma	0	1	1	2
Diopatra cuprea	49	67	18	134
Dorvilleidae	3	2	4	9
Drilonereis longa	0	0	2	2
Eteone heteropoda	43	53	36	132
Eteone lactea	1	2	2	5
Eumida sanguinea	7	3	3	13
Exogone dispar	207	1064	724	1995
Annelids (continued)				
Glycera americana	6	13	28	47
Glycera dibranchiata	1	7	1	9
Glycinde solitaria	17	29	4	50
Goniada teres	20	9	6	35
Gruebeosyllis clavata	23	58	182	263
Gyptis brevipalpa	7	11	6	24
Gyptis vittata	0	0	1	1
Hauchiella sp.	1	0	0	1
Hesione picta	6	8	1	15
Hesionidae	1	0	0	1
Heteromastus filiformis	484	637	216	1337
Heteropodarke sp. A	0	1	0	1
Hydroides dianthus	3	54	1404	1461
Kinbergonuphis sp. A	0	2	0	2
Laeonereis culveri	15	8	3	26
Leitoscoloplos foliosus	27	33	16	76
Leitoscoloplos fragilis	6	9	3	18
Leitoscoloplos robustus	5	1	3	9
Loimia viridis	0	1	3	4
Lumbrineris sp.	1	2	0	3
Lysidice ninetta	0	1	0	1
Magelona pettiboneae	13	8	0	21
Maldanidae	9	25	12	46
Marphysa sanguinea	0	2	2	4
Marphysa sp. B	0	0	1	1
Marphysa sp.	0	0	2	2
Mediomastus ambiseta	239	123	66	428

Appendix 8 (continued)

Annelids (continued)				
Mediomastus californiensis	8	38	35	81
Mediomastus sp.	170	202	90	462
Megaloma bioculatum	0	1	0	1
Melinna maculata	432	528	406	1366
Microphthalmus sczelkowii	1	2	2	5
Microspio pigmentata	5	5	0	10
Naineris bicornis	21	123	783	927
Naineris dendritica	8	5	697	710
Neanthes succinea	16	81	54	151
Nereidae	4	36	146	186
Nereiphylla fragilis	8	17	1	26
Nereis falsa	13	54	26	93
Nereis riisei	1	0	0	1
Oligochaeta	432	2438	4247	7117
Onuphidae	2	0	0	2
Orbiniidae	6	7	14	27
Owenia sp.	3	0	0	3
Paleanotus heteroseta	1	0	0	1
Parahesione cf. luteola	0	3	1	4
Paraonis fulgens	5	0	0	5
Paraprionospio pinnata	0	1	0	1
Pectinaria gouldii	12	19	8	39
Pettiboneia sp. A	1	2	0	3
Phyllodocidae	2	3	3	8
Pilargis sp.	1	0	1	2
Pista cristata	3	1	0	4
Pista palmata	3	3	2	8
Pilargidae	0	1	0	1
Platynereis dumerilli	7	40	66	113
Podarke sp.	1	0	0	1
Polydora caulleryi	1	0	0	1

Annelids (continued)				
Polydora ligni	324	607	152	1083
Polydora socialis	145	676	19	840
Polydora sp.	2	3	6	11
Prionospio cirrifera	3	5	4	12
Prionospio delta	2	7	0	9
Prionospio heterobranchia	769	3583	3609	7961
Sabaco elongatus	633	204	146	983
Sabellidae	1	2	8	11
Schistomeringos cf rudolphi	41	95	62	198
Scolelepis squamata	11	3	1	15
Scolelepis texana	36	19	9	64
Scoletoma verrilli	2	0	0	2
Scoloplos rubra	47	51	6	104
Sphaerosyllis taylori	11	16	5	32
Spio pettiboneae	25	9	6	40
Spiochaetopterus costarum	6	22	1	29
Spiophanes bombyx	2	2	0	4
Spiophanes missionensis	1	2	4	7
Spirorbis spirillum	1	3	4	8
Sthenelais sp. A	0	1	0	1
Streblospio benedicti	1774	2040	3870	7684
Syllides fulvus	0	0	3	3
Syllides bansei	47	27	51	125
Syllis cornuta	214	1103	1409	2726
Syllis lutea	81	160	275	516
Syllidae	6	15	14	35
Terebellidae	31	1	2	34
Tharyx acutus	0	0	1	1
Trypanosyllis parvidentata	0	1	1	2
Trypanosyllis vittigera	21	136	420	577
Unidentified Polychaeta	3	0	0	3

Appendix 8 (continued)

Crustaceans	4326	13617	8496	26439
Americamysis bahia	8	6	2	16
Ampelisca sp.	1706	1681	1509	4896
Ampelisca abdita	645	512	169	1326
Ampithoe valida	0	0	3	3
Batea catharinensis	1	1	2	4
Bowmaniella sp.	1	1	0	2
Caprella sp.	29	93	90	212
Caprellidae	18	246	169	433
Cerapus benthophilus	822	8743	4063	13628
Cleantis planicauda	1	0	0	1
Corophium louisianum	7	38	19	64
Corophium tuberculatum	84	0	0	84
Corophium sp.	139	90	21	250
Cumacea	51	64	65	180
Cymadusa compta	4	46	16	66
Edotea montosa	51	69	79	199
Elasmopus levis	35	187	273	495
Crustaceans (continued)				
Erichsonella attenuata	10	338	430	778
Erichthonius brasiliensis	34	99	26	159
Gammarus mucronatus	7	88	133	228
Gammarus sp.	0	14	89	103
Grandidierella bonnieroides	450	913	809	2172
Hargeria rapax (Tanaid)	86	117	239	442
Harrieta (Cymodoce) faxoni	23	135	199	357
Haustoriidae	1	0	3	4
Hyalellidae	1	5	5	11
Listriella sp.	3	1	0	4
Melita nitida	0	1	1	2
Microprotopus raneyi	0	1	0	1
Mysidacea	11	2	5	18
Orchestia sp.	0	1	0	1
Oxyurostylis smithi	39	43	31	113
Paraonidae	2	0	0	2
Xenanthura brevitelson	57	32	46	185

Molluscs	1616	1677	1335	4628
Acteocina canaliculata	2	2	5	9
Aligena texasiana	0	1	0	1
Amygdalum papyria	87	215	101	403
Anachis sp.	1	3	0	4
Anadara sp.	0	0	1	1
Anomalocardia auberiana	891	617	591	2099
Batillaria minima	1	176	5	182
Bivalvia	20	27	5	52
Brachidontes exustus	13	4	1	18
Cerithidium lutosum	0	11	5	16
Chione cancellata	7	15	7	29
Crepidula sp.	11	31	16	58
Diastoma varium	17	23	25	65
Ensis minor	3	0	0	3
Gastropoda	1	3	4	8
Haminoea antillarum	0	1	2	3
Hiatella artica	1	0	0	1
Laevicardium mortoni	15	22	11	48
Molluscs (continued)				
Lioberus castanea	1	0	4	5
Lyonsia hyalina	1	1	1	3
Macoma mitchelli	11	23	16	50
Mangelia sp	0	1	0	1
Mercenaria campechiensis	0	2	2	4
Mitrella lunata	2	11	0	13
Mulinia lateralis	334	251	370	955
Musculus lateralis	1	0	0	1
Mysella planata	1	18	0	19
Mytiloidea	5	0	0	5
Nassarius vibex	0	1	0	1
Natica sp.	1	1	0	2
Neritina virginea	0	0	1	1
Nuculana acuta	1	0	0	1
Nudibranchia	3	5	8	16
Odostomia impressa	0	0	14	14
Odostomia sp.	2	5	6	13
Olivella sp.	2	1	0	3

Appendix 8 (continued)

Molluscs (continued)					Molluscs (continued)				
Parvilucina multilineata	4	1	1	6	Tellina cristallina	0	[illegible]	0	1
Parvilucina sp.	1	1	0	2	Tellina probina	0	5	0	5
Polyplacophora	0	1	0	1	Tellina sp.	13	36	9	58
Pyrgocythara plicosa	0	1	0	1	Tellina squamifera	1	0	0	1
Rictaxis punctostriatus	13	6	16	35	Tellina tampaensis	42	41	39	122
Tagelus divisus	4	23	13	40	Tellina texana	0	3	0	3
Tagelus plebeius	1	11	1	13	Tellina versicolor	2	1	0	3
Tagelus sp	1	0	0	1	Texadina barretti	5	1	16	22
Tellina alternata	81	65	36	182	Turbonilla sp.	1	1	0	2
Tellina aquistriata	9	7	4	20	Zebina browniana	0	0	1	1
Miscellaneous	243	482	367	1092	Miscellaneous (continued)				
Actiniaria	67	237	79	383	Pentamera pulcherrima (hol)	1	1	0	2
Anoplodactylus cf. petiolatus (pyc)	2	17	14	33	Phoronis sp.	2	0	0	2
Callipallene brevirostris (pyc)	4	2	7	13	Pycnogonida	11	38	32	81
Cerebratulus lacteus (nem)	5	0	0	5	Stylochus frontalis (tur)	3	11	5	19
Holothuroidea	4	9	1	14	Thyone mexicana (hol)	1	1	10	12
Leptosynapta crassipatina (hol)	63	34	17	114	Turbellaria	12	8	10	30
Nemertea	76	149	203	428					
Total of all taxa	13705	32430	32324	78459					

Appendix 9

Fishes and decapods collected during the study period, summed over all collections by habitat. N = 180 per habitat. Organisms not identified to species were larval, juvenile, or damaged specimens. $ = species of commercial or recreational value.

	Maximum Impact	Minimum Impact	Natural Seagrass	Total
Fishes	921	2397	2032	5350
Achirus lineatus	3	2	4	9
Anchoa hepsetus	2	12	2	16
Anchoa mitchilli	93	298	118	509
Archosargus probatocephalus $	0	2	2	4
Arius felis	2	0	0	2
Bairdiella chrysoura	0	5	10	15
Bothidae	0	1	0	1
Brevoortia patronus $	546	243	49	838
Chasmodes bosquianus	0	0	1	1
Citharichthys spilopterus	4	3	0	7
Clupeidae	1	1	0	2
Cynoscion nebulosus $	3	20	12	35
Cynoscion nothus	1	0	0	1
Cyprinodon variegatus	0	2	3	5
Dasyatis sabina	0	1	0	1
Eucinostomus argenteus	2	5	5	12
Eucinostomus gula	3	0	0	3
Evorthodus lyricus	0	1	0	1
Gobiidae	1	3	1	5
Gobionellus boleosoma	4	64	60	128
Gobiosoma bosc	1	3	2	6
Gobiosoma robustum	134	854	706	1694
Harengula jaguana	0	5	0	5
Hippocampus zosterae	2	34	17	53

	Maximum Impact	Minimum Impact	Natural Seagrass	Total
Fishes (continued)				
Hypsoblennius hentzi	0	1	0	1
Hyporhamphosus unifasciatus	0	0	1	1
Lagodon rhomboides	28	419	610	1057
Leiostomus xanthurus $	21	16	26	63
Lucania parva	2	49	94	145
Menidia beryllina	6	11	15	32
Microgobius gulosus	1	0	3	4
Microgobius thalassinus	3	3	1	7
Micropogonias undulatus $	17	3	7	27
Mugil cephalus	5	0	3	8
Myrophis punctatus	8	8	9	25
Oligoplites saurus	1	0	0	1
Opsanus beta	3	16	20	39
Orthopristis chrysoptera	0	6	2	8
Paralichthys albigutta	0	1	0	1
Paralichthys lethostigma $	5	2	1	8
Strongylura marina	1	0	0	1
Symphurus plagiusa	1	11	2	14
Syngnathus scovelli	20	280	238	538
Syngnathus floridae	0	2	1	3
Syngnathus louisianae	0	3	1	4
Syngnathus sp.	0	0	3	3
Unidentified fish	0	7	3	10

Appendix 9 (continued)

Decapods				
	800	7671	6815	15286
Alpheus heterochaelis	3	217	132	352
Ambidexter symmetricus	0	1	0	1
Callianassa jamaicense	1	0	0	1
Callinectes sapidus $	57	254	189	500
Callinectes similis	49	92	78	219
Clibanarius vittatus	21	18	10	49
Dyspanopeus texanus	225	889	746	1860
Euceramos praelongus	0	1	0	1
Farfantepenaeus aztecus $	146	592	605	1343
Farfantepenaeus duorarum $	0	7	4	11
Hippolyte zostericola	151	1573	1001	2725
Libinia dubia	0	6	6	12
Litopenaeus setiferus $	7	20	22	49
Menippe mercenaria	0	0	1	1
Pachygrapsus gracilis	0	1	0	1
Pagurus criniticornis	7	280	7	294

Decapods (continued)				
Pagurus longicarpus	19	12	0	31
Pagurus pollicaris	0	1	0	1
Pagurus sp.	1	0	0	1
Palaemonetes intermedius	63	2499	2861	5423
Palaemonetes pugio	5	273	503	781
Palaemonetes vulgaris	1	18	33	52
Palaemonetes sp.	12	57	174	243
Panopeus herbstii	5	1	0	6
Panopeus turgidus	7	256	90	353
Penaeidae $	6	0	4	10
Pinnixa chaetopterana	0	3	1	4
Pinnixa lunzi	0	4	1	5
Pinnixa retinens	0	3	1	4
Rhithropanopeus harrisii	0	0	1	1
Tozeuma carolinense	11	579	345	935
Xanthidae	0	14	0	14

Appendix 10.

Sediment characteristics (as proportions) by zone and depth below sediment surface at Placement Area 194. Samples were collected within five zones: non-vegetated mud (Max = Maximum Impact) and 1-5 m, 10-15 m, 100-105 m and 1000+ m into seagrass and away from mud (Min1, Min10, Min100, and Nat (Natural Seagrass), respectively. Particle sizes: rubble > 2.0 mm; sand 0.0625 - 2.0 mm, silt 0.0040 - 0.0625 mm; clay < 0.0040 mm. N = 5 except n = 4 where mean is underlined.

			Organic content		Rubble		Sand		Silt		Clay	
Zone	Date		0-5 cm	5-10 cm	0-5 cm	5-10 cm	0-5 cm	5-10 cm	0-5 cm	5-10 cm	0-5 cm	5-10 cm
Max	Sep 95	mean	0.0769	0.0741	0.0267	0.0089	0.3022	0.6138	0.0660	0.0492	0.6052	0.3281
		se	0.0163	0.0141	0.0235	0.0094	0.0924	0.1998	0.0257	0.0180	0.0781	0.1839
	Apr 96	mean	0.0674	0.0522	0.0093	0.0234	0.3990	0.4998	0.0575	0.0359	0.5341	0.4408
		se	0.0311	0.0129	0.0081	0.0158	0.2297	0.1044	0.0244	0.0167	0.2058	0.1023
	Sep 96	mean	0.0651	0.0329	0.0175	0.0108	0.4071	0.6454	0.0407	0.0192	0.5347	0.3245
		se	0.0201	0.0236	0.0137	0.0088	0.1481	0.1032	0.0194	0.0062	0 1364	0.0998
	May 97	mean	0.0862	0.0575	0.0123	0.0080	0.1899	0.5908	0.0673	0.0345	0.7306	0.3667
		se	0.0214	0.0141	0.0195	0.0062	0.0609	0.1454	0.0171	0.0137	0.0863	0.1396
	Sep 97	mean	0.0454	0.0510	0.0157	0.0113	0 6586	0.5934	0.0252	0.0413	0.3005	0.3539
		se	0.0280	0.0219	0.0082	0.0120	0.2871	0.1989	0.0255	0.0283	0.2703	0.1810
	Apr 98	mean	0.0699	0.0553	0.0032	0.0118	0.2467	0.4996	0.0376	0.0217	0.7125	0.4669
		se	0.0179	0.0244	0.0022	0.0072	0.1126	0.1397	0.0155	0.0033	0.1055	0.1485

Appendix 10 (continued)

Min1	Sep 95	mean	0.0317	0.0669	0.0776	0.0856	0.6702	0.4713	0.0265	0.0833	0.2257	0.3597
		se	0.0168	0.0373	0.0605	0.0673	0.0712	0.1606	0.0226	0.0407	0.0933	0.1466
	Apr 96	mean	0.0250	0.0318	0.0194	0.0247	0.7539	0.7541	0.0205	0.0268	0.2061	0.1944
		se	0.0065	0.0038	0.0138	0.0193	0.0751	0.0584	0.0148	0.0145	0.0693	0.0459
	Sep 96	mean	0.0188	0.0617	0.0096	0.0175	0.5055	0.6109	0.0626	0.0501	0.4223	0.3215
		se	0.0051	0.0296	0.0038	0.0103	0.2278	0.0573	0.0408	0.0075	0.1929	0.0485
	May 97	mean	0.0762	0.0334	0.0111	0.0077	0.4969	0.7782	0.0589	0.0179	0.4330	0.1962
		se	0.0317	0.0266	0.0091	0.0067	0.1916	0.1763	0.0276	0.0153	0.1667	0.1590
	Sep 97	mean	0.0500	0.0205	0.0291	0.0330	0.5736	0.7499	0.0624	0.0388	0.3349	0.1783
		se	0.0290	0.0154	0.0310	0.0555	0.2523	0.0704	0.0376	0.0175	0.2442	0.0578
	Apr 98	mean	0.0809	0.0482	0.0029	0.0102	0.1958	0.4368	0.1729	0.1883	0.6284	0.3647
		se	0.0266	0.0311	0.0023	0.0056	0.2026	0.2639	0.2461	0.3547	0.2386	0.2376
Min10	Sep 95	mean	0.0254	0.0394	0.0434	0.0986	0.7318	0.6255	0.0625	0.0523	0.1624	0.2237
		se	0.0068	0.0121	0.0168	0.0948	0.0895	0.0985	0.0731	0.0262	0.0648	0.0826
	Apr 96	mean	0.0259	0.0363	0.0143	0.0293	0.7895	0.7332	0.0049	0.0141	0.1913	0.2233
		se	0.0177	0.0081	0.0114	0.0116	0.1246	0.0611	0.0058	0.0120	0.1163	0.0608
	Sep 96	mean	0.0405	0.0565	0.0248	0.0283	0.7836	0.7150	0.0145	0.0231	0.1772	0.2336
		se	0.0117	0.0143	0.0115	0.0144	0.0221	0.0756	0.0106	0.0248	0.0221	0.0654
	May 97	mean	0.0241	0.0400	0.0188	0.0196	0.6395	0.5707	0.0370	0.0425	0.3046	0.3673
		se	0.0077	0.0267	0.0131	0.0177	0.1311	0.2566	0.0259	0.0349	0.1199	0.2352
	Sep 97	mean	0.0742	0.0313	0.0297	0.0334	0.5857	0.7609	0.0429	0.0195	0.3416	0.1862
		se	0.0198	0.0150	0.0178	0.0314	0.1795	0.0591	0.0319	0.0166	0.1643	0.0643
	Apr 98	mean	0.0380	0.0237	0.0175	0.0104	0.5770	0.6695	0.0171	0.0368	0.3883	0.2833
		se	0.0188	0.0240	0.0192	0.0089	0.1733	0.1809	0.0135	0.0671	0.1773	0.1779

Appendix 10 (continued)

Min100	Sep 95	mean	0.0220	0.0304	0.1089	0.0770	0.7556	0.6607	0.0164	0.0418	0.1192	0.2205
		se	0.0045	0.0187	0.1018	0.0585	0.1018	0.0583	0.0044	0.0154	0.0292	0.0341
	Apr 96	mean	0.0230	0.0357	0.0419	0.0325	0.7194	0.7152	0.0093	0.0175	0.2294	0.2349
		se	0.0049	0.0081	0.0631	0.0156	0.0708	0.1040	0.0084	0.0122	0.0652	0.0840
	Sep 96	mean	0.0291	0.0355	0.0452	0.0195	0.7669	0.7418	0.0114	0.0220	0.1765	0.2167
		se	0.0134	0.0069	0.0173	0.0110	0.1102	0.0482	0.0138	0.0107	0.0912	0.0642
	May 97	mean	0.0315	0.0446	0.0179	0.0329	0.6956	0.6650	0.0367	0.0575	0.2498	0.2447
		se	0.0061	0.0220	0.0156	0.0313	0.0923	0.1078	0.0206	0.0344	0.0897	0.0691
	Sep 97	mean	0.0175	0.0351	0.0144	0.0279	0.8384	0.6673	0.0145	0.1522	0 1327	0.1525
		se	0.0054	0 0214	0.0117	0.0232	0.0396	0.2272	0.0146	0.2873	0.0325	0.0966
	Apr 98	mean	0.0173	0.0198	0.0433	0.0298	0.6630	0.6927	0.0095	0.0843	0.2841	0.1931
		se	0.0044	0.0075	0.0318	0.0180	0.0693	0.1071	0.0052	0.1321	0.0615	0.0445
Nat	Sep 95	mean	0.0336	0.0576	0.0312	0.0675	0.7987	0.7066	0.0195	0.0208	0.1506	0.2051
		se	0.0121	0.0303	0.0215	0.0281	0.0832	0.0527	0.0192	0.0107	0.0793	0.0403
	Apr 96	mean	0.0420	0.0799	0.0240	0.0303	0.7540	0.5635	0.0358	0.0380	0.1862	0.3682
		se	0.0393	0.0140	0.0184	0.0196	0.1302	0.0209	0.0266	0.0232	0.1153	0.0263
	Sep 96	mean	0.0443	0.1296	0.0434	0.0518	0.6238	0.3078	0.0423	0.0880	0.2905	0.5525
		se	0.0201	0.0119	0.0300	0.0147	0.0824	0.0331	0.0178	0.0163	0.0703	0.0401
	May 97	mean	0.0219	0.0658	0.0286	0.0526	0.8076	0.6722	0.0200	0.0456	0.1437	0.2295
		se	0.0068	0.0270	0.0302	0.0333	0.0432	0.1301	0.0129	0.0203	0.0253	0.1264
	Sep 97	mean	0.0246	0.0365	0.0396	0.0615	0.7895	0.7452	0.0279	0.0231	0.1430	0.1702
		se	0.0090	0.0334	0.0354	0.0405	0 0972	0.0862	0.0217	0.0135	0.0557	0.0705
	Apr 98	mean	0.0201	0.0619	0.0296	0.0323	0.7783	0.5361	0.0115	0.0479	0.1806	0.3837
		se	0.0068	0.0330	0.0232	0.0152	0.0686	0.1536	0.0046	0.0371	0 0732	0.1321

Appendix 11.

Water column and seagrass characteristics at Placement Area 194. Samples were collected in five zones: non-vegetated mud (Max = Maximum Impact) and 1-5 m, 10-15 m, 100-105 m and 1000+ m into seagrass and away from mud [Min1, Min10, Min100, and Nat (Natural Seagrass), respectively]. N = 5 except where mean is underlined (n = 2) or se is indicated by a dash (n = 1). Biomass = g dry weight per 58.9 sq. cm. RSR = root : shoot ratio.

Zone	Date		Temperature (C)	Salinity	Depth (cm)	Turbidity (NTU)	% Cover	Shoot Biomass	Root Biomass	RSR
Max	Sep 95	mean	28.6	37.0	36.0	13.3	0.0	0.0000	0.0000	0.00
		se	0.5	3.2	4.0	7.6	0.0	0.0000	0.0000	0.00
	Apr 96	mean	24.0	39.6	33.5	33.8	8.8	0.0077	0.0076	0.20
		se	0.1	0.5	8.9	13.8	8.2	0.0173	0.0169	0.44
	Sep 96	mean	32.4	44.2	52.2	29.2	0.0	0.0000	0.0000	0.00
		se	0.5	0.4	6.3	18.2	0.0	0.0000	0.0000	0.00
	May 97	mean	27.0	39.4	62.2	43.0	4.0	0.0000	0.0000	0.00
		se	0.1	2.5	4.3	24.0	2.8	0.0000	0.0000	0.00
	Sep 97	mean	28.6	47.8	75.2	7.6	29.6	0.0163	0.0355	0.44
		se	0.5	0.8	22.6	4.8	35.6	0.0364	0.0795	0.98
	Apr 98	mean	23.6	32.2	89.2	24.6	48.8	0.0053	0.0102	0.94
		se	0.1	1.3	4.6	12.5	30.6	0.0081	0.0139	1.48

Appendix 11 (continued)

Min1	Sep 95	mean	29.0	36.6	55.6	5.8	100.0	0.5156	0.7221	1.72
		se	1.0	3.3	6.6	0.7	0.0	0.2440	0.3733	1.23
	Apr 96	mean	24.6	39.8	36.7	15.8	96.8	0.1030	0.1952	3.26
		se	0.5	0.4	6.3	2.5	5.2	0.1622	0.1872	1.80
	Sep 96	mean	30.2	45.2	41.6	28.6	91.2	0.4850	0.4303	1.02
		se	0.4	1.1	2.3	18.5	10.0	0.3132	0.1911	0.38
	May 97	mean	28.0	40.2	62.6	8.2	92.8	0.2373	0.4533	1.82
		se	0.0	1.3	9.5	3.8	14.0	0.2145	0.5941	1.15
	Sep 97	mean	28.6	49.2	52.4	4.3	100.0	0.0259	0.0527	2.03
		se	0.2	0.8	10.1	3.2	0.0	-	-	-
	Apr 98	mean	23.5	31.2	59.3	25.4	61.6	0.0474	0.0544	0.59
		se	0.0	0.4	4.2	2.9	38.0	0.0583	0.0745	0.70
Min10	Sep 95	mean	29.8	35.0	59.7	5.4	100.0	0.5349	0.7723	1.68
		se	0.4	3.7	12.5	1.0	0.0	0.1971	0.1900	1.03
	Apr 96	mean	22.2	42.2	47.9	15.6	100.0	0.1530	0.6962	4.71
		se	0.4	0.4	9.4	5.6	0.0	0.0475	0.3228	2.17
	Sep 96	mean	33.8	43.6	58.5	14.4	100.0	0.3327	0.5432	2.81
		se	0.4	0.9	6.3	5.7	0.0	0.2000	0.1211	3.14
	May 97	mean	28.0	41.4	56.2	10.0	91.2	0.2267	0.3874	1.78
		se	0.0	1.5	4.6	7.3	19.7	0.1453	0.3071	0.72
	Sep 97	mean	30.5	48.6	52.8	10.6	100.0	0.6325	0.7779	1.26
		se	0.6	1.1	14.2	5.6	0.0	0.1414	0.0040	0.28
	Apr 98	mean	23.9	31.4	52.8	22.8	70.4	0.1380	0.2805	1.61
		se	0.3	0.5	9.4	5.4	39.7	0.1183	0.2549	1.19

Appendix 11 (continued)

Min100	Sep 95	mean	31.0	33.6	62.3	6.0	100.0	0.4893	0.9616	2.65
		se	0.0	2.8	9.5	1.7	0.0	0.2782	0.2666	1.77
	Apr 96	mean	20.8	43.0	73.1	10.4	100.0	0.2118	0.5911	3.00
		se	0.4	0.0	10.1	2.2	0.0	0.1462	0.3912	1.42
	Sep 96	mean	33.2	45.4	56.2	11.6	100.0	1.0578	0.9057	1.25
		se	0.4	0.9	2.6	7.0	0.0	0.5110	0.2519	1.13
	May 97	mean	28.0	34.6	66.1	7.8	93.6	0.3799	1.0185	2.83
		se	0.0	0.9	6.4	1.8	14.3	0.2279	0.5984	2.00
	Sep 97	mean	31.1	45.8	73.9	5.5	100.0	0.3859	1.2048	3.38
		se	0.3	1.1	4.1	1.5	0.0	0.1934	0.4185	1.15
	Apr 98	mean	24.4	30.0	88.9	15.0	99.2	0.0648	0.2689	8.90
		se	0.0	0.0	6.3	2.1	1.8	0.0765	0.3443	10.00
Nat	Sep 95	mean	31.2	35.4	73.5	6.2	100.0	0.2583	0.4777	2.35
		se	0.4	3.3	4.3	1.2	0.0	0.1713	0.2789	1.46
	Apr 96	mean	21.6	41.8	61.4	23.4	100.0	0.1918	0.3698	2.11
		se	0.5	1.1	3.5	2.1	0.0	0.0807	0.1536	1.18
	Sep 96	mean	30.4	49.4	67.8	5.6	100.0	1.5511	1.2036	0.77
		se	0.5	1.3	3.3	1.7	0.0	0.9390	0.3093	0.07
	May 97	mean	27.2	33.8	63.3	7.6	100.0	1.1937	1.9702	2.61
		se	0.3	1.8	4.0	1.3	0.0	0.9390	0.6224	1.78
	Sep 97	mean	31.6	48.4	74.2	5.2	96.0	0.3918	0.6551	1.68
		se	0.1	2.2	10.3	2.3	8.9	0.0220	0.0049	0.11
	Apr 98	mean	25.5	28.2	60.9	36.4	100.0	0.1049	0.4821	2.09
		se	0.3	0.8	6.5	9.4	0.0	0.1616	0.6673	3.06

Appendix 12

Benthic organisms collected at Placement Area 194. Samples were collected in five zones: non-vegetated mud (Max = Maximum Impact) and 1-5 m, 10-15 m, 100-105 m and 1000+ m into seagrass and away from mud [Min1, Min10, Min100, and Nat (Natural Seagrass), respectively]. N = 30 per zone. Species identified by letters (e.g., Autolytus sp. A) refer to designations by Uebelacker and Johnson (1984). Organisms not identified to species (i.e., to phylum, class, subclass, order, family, or genus) generally were juvenile or damaged specimens.

	Maximum	Minimum Impact			Natural	
	Impact	1-5 m	10-15 m	100-105 m	Seagrass	Total
Annelids	1280	2177	2062	2364	3778	11661
Aphelochaeta marioni	2	2	1	0	0	5
Arenicola cristata	0	4	1	0	1	6
Aricidea fragilis	0	0	0	0	1	1
Armandia maculata	0	0	0	2	0	2
Autolytus sp. A	1	1	0	2	0	4
Brania sp. A	0	0	0	1	0	1
Capitella capitata	105	103	106	72	99	485
Capitella giardi	0	6	2	5	0	13
Capitella jonesi	0	0	0	2	0	2
Capitellidae	0	0	2	1	0	3
Ceratonereis irritabilis	0	1	1	0	0	2
Ceratonereis versipedata	8	0	0	3	0	11
Chone cf. americana	153	83	90	221	80	627
Diopatra cuprea	8	13	9	11	0	41
Dorvilleidae	0	1	2	0	0	3
Eteone heteropoda	1	3	13	1	6	24
Eteone lactea	0	1	0	0	0	1
Exogone dispar	23	258	75	104	63	523
Genetyllis sp.	0	0	1	1	0	2
Glycera americana	0	0	0	0	23	23
Glycinde solitaria	1	9	4	4	0	18
Goniada teres	2	2	0	0	0	4
Gruebeosyllis clavata	0	19	3	25	6	53
Gyptis brevipalpa	2	1	0	2	0	5
Hesione picta	0	4	0	0	0	4
Heteromastus filiformis	10	8	10	3	15	46
Laeonereis culveri	1	2	5	0	0	8
Leitoscoloplos foliosus	7	4	1	2	1	15
Leitoscoloplos fragilis	0	1	0	1	0	2
Leitoscoloplos robustus	0	0	0	3	0	3
Lumbrineris sp.	0	1	0	0	0	1
Magelona pettiboneae	1	0	0	1	0	2
Maldanidae	1	2	9	2	0	14

	Maximum	Minimum Impact			Natural	
	Impact	1-5 m	10-15 m	100-105 m	Seagrass	Total
Annelids (continued)						
Marphysa sanguinea	0	1	0	0	0	1
Mediomastus ambiseta	21	21	17	50	0	109
Mediomastus californiensis	49	19	15	43	1	127
Mediomastus sp.	0	0	0	1	0	1
Melinna maculata	60	32	17	84	13	206
Microspio pigmentata	0	2	0	0	0	2
Naineris bicornis	16	21	44	50	331	462
Naineris dendritica	0	0	0	2	169	171
Neanthes succinea	2	13	24	9	12	60
Nereidae	0	0	7	16	140	163
Nereiphylla fragilis	0	3	1	1	0	5
Nereis falsa	3	14	10	14	3	44
Oligochaetes	46	614	720	804	1432	3616
Orbiniidae	0	0	1	0	0	1
Pectinaria gouldii	4	5	3	4	0	16
Phyllodocidae	0	0	1	0	0	1
Platynereis dumerilli	2	4	2	3	6	17
Polydora ligni	7	49	21	35	9	121
Polydora socialis	2	0	4	27	4	37
Polydora sp.	0	1	0	0	0	1
Prionospio cirrifera	0	0	0	0	2	2
Prionospio heterobranchia	129	563	465	396	759	2312
Sabaco elongatus	387	80	48	77	1	593
Sabellidae	0	0	1	0	1	2
Schistomeringos cf. rudolphi	15	19	13	17	8	72
Scolelepis squamata	0	1	0	0	0	1
Scolelepis texana	3	3	5	0	1	12
Scoloplos rubra	14	11	7	10	3	45
Sphaerosyllis taylori	0	4	0	3	0	7
Spio pettiboneae	2	0	0	0	0	2
Streblospio benedicti	162	30	11	2	51	256
Syllidae	0	0	6	0	0	6
Syllides bansei	0	1	0	1	5	7

Appendix 12 (continued)

Annelids (continued)						
Syllides fulvus	23	86	216	226	279	830
Syllis cornuta (Syllidae A)	3	13	37	12	72	137
Syllis lutea	0	8	2	0	7	17
Crustaceans	207	1169	1368	730	730	4204
Americamysis bahia	5	4	1	0	0	10
Ampelisca abdita	20	22	18	22	7	89
Ampelisca sp.	43	25	25	46	5	144
Amphipoda	0	2	0	0	5	7
Bowmaniella sp.	0	0	5	0	0	5
Caprella sp.	24	5	3	7	6	45
Caprellidae	1	37	53	27	38	156
Cerapus benthophilus	17	749	915	210	191	2082
Corophium louisianum	0	1	1	3	0	5
Corophium sp.	1	0	0	0	0	1
Cumacea	10	7	10	5	3	35
Cymadusa compta	0	11	1	12	1	25
Edotea montosa	4	12	7	14	15	52
Elasmopus levis	7	13	5	30	75	130
Molluscs	317	340	245	216	172	1290
Acteocina canaliculata	0	0	0	1	0	1
Amygdalum papyria	22	71	37	37	30	197
Anomalocardia auberiana	220	176	139	102	80	717
Batillaria minima	0	2	0	0	0	2
Bivalvia	7	3	0	1	1	12
Chione cancellata	0	3	0	0	0	3
Diastoma varium	2	3	0	1	1	7
Ensis minor	2	0	0	0	0	2
Gastropoda	0	1	0	0	1	2
Laevicardium mortoni	0	2	4	1	1	8
Macoma mitchelli	2	3	1	3	0	9
Mulinia lateralis	37	39	23	28	19	146
Miscellaneous	20	65	106	78	35	304
Actiniaria	2	37	67	15	7	128
Anoplodactylus cf. petiolatus (pyc)	0	0	1	0	0	1
Callipallene brevirostris (pyc)	0	1	4	6	1	12
Cerebratulus lacteus (nem)	0	0	2	0	0	2
Holothuroidea	1	3	0	2	0	6
Leptosynapta crassipatina (hol)	9	2	9	8	0	28
Total of all taxa	1867	3794	3844	3438	4766	17709

Annelids (continued)						
Terebellidae	0	0	1	1	0	2
Trypanosyllis vittigera	4	33	73	69	216	395
Crustaceans (continued)						
Erichsonella attenuata	0	85	78	77	122	362
Erichthonius brasiliensis	2	8	9	19	0	38
Gammarus mucronatus	2	14	15	37	47	115
Gammarus sp.	0	7	25	1	21	54
Grandidierella bonnieroides	47	133	137	156	107	580
Haminoea antillarum	0	0	0	1	0	1
Hargeria rapax	3	1	3	4	39	50
Harrieta faxoni	5	19	45	40	47	156
Hyalellidae	1	3	0	3	4	11
Listriella sp.	1	0	0	1	0	2
Mysidacea	3	1	0	0	0	4
Orchestia sp.	0	0	0	9	0	9
Oxyurostylis smithi	11	10	11	5	5	42
Xenanthura brevitelson	0	0	1	0	0	1
Molluscs (continued)						
Nudibranchia	0	1	3	4	4	12
Odostomia impressa	0	0	0	0	14	14
Parvilucina multilineata	0	1	0	0	0	1
Tagelus divisus	0	12	9	6	4	31
Tellina alternata	19	10	15	15	2	61
Tellina aquistriata	0	0	1	1	0	2
Tellina sp.	2	6	0	9	0	17
Tellina tampaensis	4	6	12	2	3	27
Tellina texana	0	1	0	1	0	2
Texadina barretti	0	0	1	2	10	13
Turbonilla sp.	0	0	0	1	0	1
Miscellaneous (continued)						
Nemertea	5	26	31	41	16	119
Pycnogonida	2	7	2	5	5	21
Stylochus frontalis (tur)	0	0	0	0	2	2
Thyone mexicana (hol)	0	0	0	2	3	5
Turbellaria	1	2	0	1	1	5

Appendix 13.

Fishes and decapods collected at Placement Area 194. Samples were collected in five zones: non-vegetated mud (Max = Maximum Impact) and 1-5 m, 10-15 m, 100-105 m and 1000+ m into seagrass and away from mud [Min1, Min10, Min100, and Nat (Natural Seagrass), respectively]. N = 30 per zone. Organisms not identified to species (i.e., to family or genus) generally were juvenile or damaged specimens. $ = species of commercial or recreational value.

	Maximum Impact	Minimum Impact 1-5 m	10-15 m	100-105 m	Natural Seagrass	Total
Fishes	106	405	279	237	219	1246
Anchoa hepsetus	0	1	0	0	0	1
Anchoa mitchilli	42	196	73	24	58	393
Brevoortia patronus $	18	2	4	16	2	42
Cynoscion nebulosus $	0	1	3	1	1	6
Cyprinodon variegatus	0	0	0	1	2	3
Gobiidae	1	6	4	4	0	15
Gobionellus boleosoma	0	1	0	0	1	2
Gobiosoma bosc	0	2	0	1	0	3
Harengula jaguana	15	91	92	75	48	321
Lagodon rhomboides	10	30	40	41	25	146
Leiostomus xanthurus $	2	0	0	0	0	2
Lucania parva	0	9	6	6	34	55
Menidia beryllina	4	9	2	28	10	53
Microgobius gulosus	1	1	0	0	0	2
Microgobius thalassinus	1	0	0	0	2	3
Micropogonias undulatus $	1	0	0	0	0	1
Mugil cephalus	1	0	0	0	0	1
Myrophis punctatus	1	1	3	0	0	5
Opsanus beta	0	4	6	5	4	19
Strongylura marina	1	0	0	0	0	1
Syngnathus scovelli	8	50	46	35	32	171
Unidentified fish	0	1	0	0	0	1
Decapods	45	862	1037	1281	1061	4286
Alpheus heterochaelis	0	25	62	17	10	114
Callinectes sapidus $	0	1	3	3	0	7
Callinectes similis	0	0	0	1	0	1
Dyspanopeus texanus	7	43	55	47	99	251
Farfantepenaeus aztecus $	11	16	27	25	20	99
Hippolyte zostericola	11	74	109	68	86	348
Libinia dubia	0	1	1	0	1	3
Litopenaeus setiferus $	3	11	2	1	5	22
Pagurus criniticornis	0	1	2	0	0	3
Pagurus longicarpus	1	0	0	1	0	2
Palaemonetes intermedius	9	622	704	1065	786	3186
Palaemonetes pugio	1	54	51	34	35	175
Palaemonetes vulgaris	0	3	13	5	10	31
Palaemonetes sp.	1	8	6	8	8	31
Panopeus turgidus	0	2	0	0	1	3
Penaeidae $	1	0	0	1	0	2
Pinnixa retinens	0	0	0	1	0	1
Tozeuma carolinense	0	1	2	4	0	7